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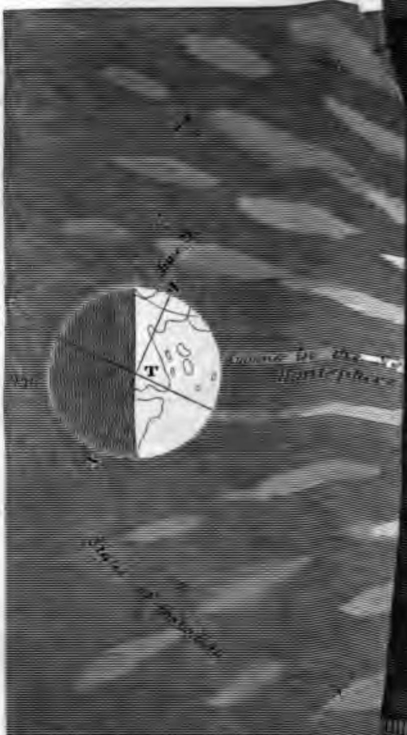

VARIATIONS

AN

EASY GRAMMAR

169

OF

NATURAL AND EXPERIMENTAL PHILOSOPHY.

FOR THE USE OF SCHOOLS.

WITH TEN ENGRAVINGS.

BY DAVID BLAIR, A. M.

AUTHOR OF THE CLASS BOOK, READING EXERCISES, &c.

SECOND EDITION

REVISED AND ENLARGED

BY BENJAMIN HALLOWELL.

PHILADELPHIA:
MBER & SHARPLESS, 8, SO. FOURTH.
John Bioren Printer.
1832.

Eastern District of Pennsylvania, to wit:
BE IT REMEMBERED, that on the twenty-sixth c
of February, in the fifty-third year of the Independenc
the United States of America, A. D. 1829, KIMBER
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the title of a book, the right whereof they claim as p
prietors, in the words following, to wit:—

'An Easy Grammar of Natural and Experimental Phi
sophy. For the Use of Schools. With Ten Engravin
By DAVID BLAIR, A. M. Author of the Class Book, Re
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HALLOWELL.'

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D. CALDWELL,
Clerk of the Eastern District of Pennsylvania.

PREFACE.

The Author of the following pages is aware that there already exist several valuable books on Natural and Experimental Philosophy, and he should not have presumed to add to their number, except for the purpose of reducing so important a branch of knowledge to the level of the business of schools.

Every instructor of youth must be aware, that mere disquisition is of no use in the art of teaching, and that no science can be taught, if the student does not *work* or perform operations in it.

A grown person might read all the books which exist relative to any Science, and yet remain totally ignoran its principles, and be unable to ap them, or reason about them, if he d not patiently commit to memory its a ioms, definitions, and leading division and if he did not apply these himself to the practice of the science in which he is desirous to become a proficient. He who only reads about a science can be nothing more than a smatterer, while he who commits its terms and elementary principles to memory, and applies them by his own act to the various combinations of the science soon becomes a master of it.

Such being the case with persons of mature age, how is it to be expected that young persons, who seldom learn any thing by force of reasoning, and who acquire knowledge only by mechanical means, should become proficients, except by committing the elementary principles of a science to memory, and exercising themselves in its practice?

In strict conformity with this feeling, the Grammar of Natural Philosophy, has been compiled. All the definitions and elementary principles have been written with a studied brevity, so that they may be learnt by rote. With these have been intermixed such easy and familiar Experiments and Illustrations, as will enable the young student to work in each science, and at the same time render its principles intelligible to the lowest capacity. The exercises and questions have been drawn up in such a manner, as that, in answering them, the student may be forced to apply the several experiments, and reflect on what he has previously committed to memory. The Glossary explains many things, which could not be introduced, agreeably to good method, among the definitions. And, finally, the Plates tend to illustrate the experiments, and render unnecessary some of the apparatus which they represent.

If the Author has not been equally happy in every department, he will feel it a distinction to be honoured with observations of intelligent Tutors, and he shall thankfully avail himself, in a future edition, of every improvement which may be so suggested to him.

He cannot let pass this favourable opportunity to express his sense of the honour which has been rendered to his humble endeavours, in the two works which he has already submitted to the public. He alludes to his *Class Book*, and his *Exercises in Reading*, in both of which he laboured diligently to give a popular feature to useful knowledge, and he has met with his reward in the unparalleled success of his books. The letters of approbation which he has received from the heads of public seminaries, the almost universal adoption of these works by intelligent teachers, in every part of the world where the English language is taught, and the actual sale of nearly TEN THOUSAND copies of each book within a year after its publication, are testimonies, of which it has been the lot of few authors to boast.

He hopes the present work will not diminish the reputation he has acquired!

DAVID BLAIR.

ADVERTISEMENT.

The alterations made in the present edition of Blair's Philosophy, are such as have been suggested by experience, in using the work for a number of years, and such as it is believed will render it more generally useful. In the late American editions, there are parts which appear to be too abstruse for an elementary work, and which, indeed, are considered only as speculations by pretty eminent philosophers. Of this kind are the remarks upon the causes of gravitation and magnetism, and some others.

In Astronomy, the lists of the elements of the planets, some of which are entirely unexplained in the work, have been found to embarrass the learner. It is a fact taught by experience, that whenever a student has to omit a part of his work beyond his capacity, it has a discouraging tendency. The present Editor has therefore endeavoured to replace those parts by more useful matter, and he thinks he has not been entirely unsuccessful. He has interspersed additional interesting facts throughout the whole of the work, and *particularly* under the subjects of Hydrostatics, Pneumatics, Optics, and Astronomy.

In Astronomy, the list of visible eclipses of the Sun and Moon, and transits of Mercury and Venus, it is believed, will be interesting. The explanation of the cause of the blue appearance of the heavens, of hail in warm weather, of the twinkling of the stars, and the deception in the number visible to the naked eye on a clear evening, the Editor believes to be entirely original.

The effect of *Caloric* on bodies is so intimately connected with some parts of philosophy, particularly in the causes of winds, rains, dew, &c. that an article upon that subject has been added, embodying the most of the interesting facts. The present arrangement of the questions, it is believed, will contribute to the ease of the student in prosecuting his studies, by bringing his attention to the facts desired to be remembered.

BENJAMIN HALLOWELL.

Alexandria Boarding School, 2nd. Month, 1829.

A GRAMMAR

OF

NATURAL PHILOSOPHY.

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1. The word PHILOSOPHY is of Greek origin, and means the *love of knowledge.*

2. Philosophy is divided into *moral* and *natural.*

3. *Moral Philosophy* treats of the *manners,* the *duties,* and the *conduct* of *man,* considered as a rational being.

4. *Natural Philosophy* proposes for its object the *knowledge* of the *phenomena* of *nature.*

5. The axioms of philosophy which have been deduced from experience, are,

I. *Nothing* has no property; hence,

II. No *substance* or *thing* can be produced from nothing.

III. Matter cannot be *annihilated,* or reduced to nothing.

Observation. Though many things appear to be utterly destroyed, as by the action of fire, evaporation, &c. yet the substances are not annihilated, but are only dispersed, or divided into particles so minute as to elude our senses.

IV. Every *effect* has a cause, and is proportionate to it.

OF MATTER AND ITS PROPERTIES.

6. MATTER is the general name of ever thing or substance that has length, breadth and thickness.

7. The inherent properties of all matter are SOLIDITY, DIVISIBILITY, MOBILITY, and INERTNESS.

8. *Solidity* is that property which ever body possesses, of not permitting any othe body to occupy the same place with it, at th same time.

Illustration 1. If a piece of wood or metal occupy certain space, before any thing else can take possessio of that space, the wood or metal must be removed.

2. *Water* and even *air*, have this property.

Experiment 1. If some water be put into a tube close at one end, and a piece of wood be inserted that fits th inside of the tube very accurately, it will be impossible t get the wooden piston to the bottom of the tube, unles the water is taken away.

2 The experiment may also be made with air instea of water.

Corollary. Therefore, water, air, and all other fluid are in a certain space, equally solid with the hardes body.

9. *Divisibility* is that property of matter, b which its parts may be separated from eac *other. Of this* there can be no end.

Illustration 1. Since matter can never be *annihilated* by division, so we can never imagine it to be cut into such small particles, that any one of them shall not have an upper and an under surface, which may be separated, if we have instruments fine enough for the purpose.

2. It would also be absurd to say, that the greatest mass has more halves, quarters, or thousandth parts, than the smallest particle of matter.

Experiment 1. If a grain of gold be melted with a pound or 5760 grains of silver, and a single grain of the mass be dissolved in diluted nitric acid, the gold, which is only the 5761st part of a grain, will fall to the bottom, and be visible.

2. A grain of gold may be hammered by the gold-beaters to such a degree of fineness, that the two-millionth part of the grain can be seen by the naked eye.

3. In addition to these experiments we may observe, that there are animalculæ so small, that many thousands of them taken together are smaller than the point of a needle. A particle of the blood of one of these animals must be inconceivably small.

4. The particles of light are still more minute, or we dare not open our eyes.

Corollary. From all which it is evident, that matter is actually divisible to a degree much greater than we can imagine; and to which we can set no limits.

10. *Mobility* is that property of matter, by which it is capable of being moved from one part of space to another.

Illustration. It is found from experiment and observation, that all matter is capable of being moved, if a sufficient force can be applied for the purpose. Archimedes thought he could move the *world*, if he had a place to rest his lever.

11. *Inertness*, or inactivity, is that property of matter, by which it would always continue in the same state of rest or motion in which it is, unless prevented by some external force.

Illustration 1. It is evident that matter, as a stone, can never put itself in motion.

2. Bodies in motion, as a bowl on the ground, or a cannon ball passing through the air, fall from motion to a state of rest, either by the friction of the earth, by the gravity or weight of the body, or by the resistance of the air.

Experiment 1. A marble shot from the fingers would run but a small distance on a carpet; its motion would be continued much longer on a flat pavement; and longer still on fine smooth ice. Here the friction is greatest on the carpet and least on the ice. If the friction were quite removed, and the resistance of the air also, the marble once put in motion would continue in that state for ever.

2. If a ball were fired from a cannon with a *certain* velocity, and there were no resistance from the air, it would circulate round the earth perpetually, and never come to a state of rest. In this manner the moon goes round the earth.

3. If a person were standing in a boat at rest, and the boat were suddenly pushed from the shore, he would be in danger of falling backwards. And if a boat in swift motion be stopped before the person is aware, he will fall forwards; because his tendency will then be to continue in the same state of motion.

4. This principle is applicable to the motion on horses or in carriages.

OF ATTRACTION AND REPULSION.

12. By ATTRACTION is meant, the tendency that bodies have to approach each other.

13. There are five kinds of attraction: viz. the attraction of *cohesion*; of *gravitation*; of *electricity*; of *magnetism*; and *chemical* attractions.

14. The *attraction* of *cohesion* is that by which the small particles of matter are kept together. By this principle bodies preserve their forms, and are prevented from falling to pieces.

15. The attraction of cohesion takes place between bodies only when they are at very small distances from each other; and the *nearer* they are, the more strongly is this attraction exerted.

Illustration 1. Heat expands all bodies by separating the particles; heat, therefore, continually diminishes the attraction of cohesion.

2. Ice of the same thickness is much stronger when the weather is very cold, because then the particles are nearer together.

3. In the melting of bodies, heat overcomes the attraction of cohesion by separating the particles.

4. When any thing is broken, as glass, china, &c. it is the attraction of cohesion that is overcome; if the particles could be brought as closely in contact as they were before, they would adhere with as much firmness as ever.

Experiment 1. If two leaden bullets be scraped very clean, and squeezed together, they will adhere so firmly as to require a considerable force to separate them.

2. When two pieces of iron are heated to a certain degree and hammered together, the particles of the two pieces are brought so near, that they adhere with as much firmness as in any other part. This is called, *welding*.

3. If some water be placed between two panes of glass, they will adhere with considreable force. This explains the principle of *soldering*, *glueing*, &c.

4. If two globules of quicksilver be placed near each other, they will run together, and become one drop.

16. *Capillary* attraction is reckoned a species of cohesion.

Experiment 1. If a small glass tube, open at both ends, be dipped in water, the water will rise in the tube higher than its level in the basin. The smaller the bore of the tube, the higher will the water rise.

2. Take two pieces of glass five or six inches square, join any two of their sides, and separate the opposite sides with a small piece of stick, so that the surfaces may form a small angle; then immerse them about an inch deep in a basin of coloured water, and the water will rise between the glasses and form a curve.

3. A piece of sugar, or sponge, will draw up water, or any other fluid, upon the same principle.

17. It is, probably, owing to the various degrees of cohesion, that some bodies are hard, and others soft; that some are in a solid, others in a fluid state.

18. Repulsion is a force that is supposed to extend to a small distance round bodies, and prevent them from coming into actual contact.

19. Where the sphere of attraction ends, a repulsive force begins.

Illustration. The repelling force of the particles of a fluid is but small, and therefore, if a fluid be divided, it readily unites again. But if a hard substance, as glass, or sealing wax be broken, the parts cannot be made to adhere, unless they are melted in one instance, or moistened in the other.

Experiment 1. Water repels most bodies till they are wet. A small sewing needle will swim on a basin of water.

2. Drops of water will roll on the leaves of many vegetables without wetting them.

3. If a ball of light wood be dipped in oil, and put into a pan of water, the water will be repelled from the wood, and will form a channel round it.

Observation. Although these experiments are intended to illustrate *repulsion*, they certainly are only instances of *attraction.* In the first experiment, the attraction of the particles of water is too great to be overcome by the weight of the needle. In the second, the attraction of the particles of water for each other, is greater than their attraction for the leaves of the vegetable, &c.

20. The attraction of *gravitation* or *gravity* is that force, by which distant bodies tend towards one another.

21. By gravity, a stone dropped from a height, falls to the surface of the earth; and by

it the heavenly bodies are retained in t
orbits.

Observation. Experience, reasoning, and analogy,
that gravitation exists, not only between the earth and
surrounding bodies, but between all parts of matter. O
terrestrial body gravitates or tends towards another terr
trial body; the moon gravitates towards the earth; t
moon, the earth, and all the planets, gravitate towar
each other, and towards the sun; and probably the su
with all its planetary system, may gravitate towards so
other object.

22. The planets gravitate towards the su
and towards each other, as well as the su
towards them.

23. By gravity, all terrestrial bodies ten
towards the centre of the earth.

Observation. Smoke, vapour, &c. appear to be exce
tions to this; but they rise in consequence of the air bein
heavier than they are, like a piece of light wood plac
at the bottom of water will rise to the top.

24. In all places equally distant from th
centre of the earth, the force of gravity i
equal.

25. The force of gravity is less at the equa
tor than it is at the poles, because the equato
rial diameter is about twenty-five miles longe
than the polar diameter.

26. The force of gravity is greatest at th
earth's surface, from whence it decreases up
wards and downwards.

27. It decreases upwards as the square of the distance from the centre, and downwards simply as the distance.

Illustration. At *double* the distance from the centre *above* the *surface*, the force of gravity would be only one-fourth of what it is at the surface, and at three times the distance, the force would be only one-ninth. At the distance of half a semi-diameter from the *centre*, the force would be only one-half what it is at the surface: at one-third of the semi-diameter, the force would be one-third, and so on. A body placed at the centre would be attracted equally on all opposite sides, and would therefore have no tendency to move in any direction.

Observation 1. What the *cause* of gravitation is, or how *one* body can act upon *another* body through a certain space, is a question that naturally presents itself to the inquisitive mind, but which philosophers are utterly incapable of answering. All they can say is, that the effect is certain, the knowledge of its laws is highly useful to mankind, but its *cause* is hidden among the mysteries of nature.

Observation 2. Since the surface of the earth gradually increases in its distance from the centre, as we go from the poles towards the equator, the mouths ef all rivers that run towards the equator, are further from the centre of the earth than their sources are. Hence they may be said to *run up hill.* In this way, the Mississippi river runs up hill about three miles. This is owing to the centrifugal force, produced by the earth turning on its axis.

OF MOTION.

28. Motion is a continued and successi
change of place.

29. Nothing can be produced or destroy
without motion, and every thing that happe
depends upon it.

30. The general laws of motion are,

I. Every body will continue in its state
rest, or of uniform motion in a right line, u
less it be compelled to change that state
some external force.

II. The change of motion is always in pr
portion to the moving force impressed, and
always made according to the right line
which that force is impressed.

III. Action and re-action are always equ
and contrary.

Observation 1. When the earth attracts a stone, t
stone attracts the earth with an equal force.

2. If a body be struck by a hammer, the hammer
struck by the body just as hard.

Exp. If a person will place a large stone against
breast, it may be struck by a hammer without his expe
encing any inconvenience.

31. We are chiefly concerned with tw
kinds of motion: 1. That by which an enti
body is transferred from one place to anothe

2. The motion of the parts of bodies among themselves.

Illustration. By the first kind of motion, a heavy body falls to the surface of the earth, a carriage moves, and a ship sails. It is by the second that plants and animals grow, and the compositions and decompositions of bodies take place.

Experiment 1. Take a decanter of clear water, and hold it in the rays of the sun, and you will see that the light particles contained in it are in perpetual motion.

2. Let the rays of the sun pass through a small hole in the window shutter, and you will observe the particles floating in the atmosphere are in constant motion, of whose existence you were not before aware.

32. There are several things to be noticed with regard to motion; 1. The force which impresses the motion. 2. The quanity of matter in the moving body. 3. The velocity and direction of motion. 4. The space passed over by the moving body. 5. The time employed in going over this space. And, 6. The force with which it strikes another body that is opposed to it.

33. Every body, by its inertness, resists all change of state; therefore, to put a body in motion, there must be sufficient cause.

34. The causes of motion are called motive powers: these are the motion of men and other animals, wind, water, gravity, the pressure of the atmosphere, and steam.

35. The velocity of motion is estimated by the time employed in moving over a certain space, or by the space passed over in a certain time. The less the time, and the greater the space moved over, the greater is the velocity.

36. To ascertain the degree of velocity, the space run over must be divided by the time.

Example 1. If a ship sail at the rate of twelve miles in an hour, or sixty minutes, then the velocity is equal to one mile in five minutes.

2. If two persons set out together on a journey, and one walk two and a half miles, and the other walk five miles an hour, the velocity of the latter will be double that of the former.

37. To measure the space run over, the velocity must be multiplied by the time.

Illustration. It is evident, that if either the velocity or the time be increased, the space run over will likewise be increased.

Example. If the velocity be doubled, then the body will move over twice the space in the same time: if the time be twice as great, then the space will be doubled: hence if the velocity and time be both doubled, then will the space be four times as great.

38. A body in motion must every instant tend to some point.

39. It may tend always to the same point, in which case the motion will be in a straight line.

40. It may be continually changing the

point to which its motion is directed: and this will produce a curvilinear or circular motion.

41. If a body is acted upon by only one force, or by several forces in the same direction, its motion will be in the same direction in which the moving force acts.

Example. The motion of a boat, which a man draws to him with a rope, is of this kind.

42. If two or more forces, differently directed, act upon the same body at the same time, as it cannot obey them all, it will move in a direction somewhere between them. This is called the *composition* and *resolution* of motion.

Illustration. Suppose a body, A, plate I. fig. 1, to be acted upon by another body in the direction AB, while at the same time it is impelled in the direction AC; then it will move in the direction AD. If the lines AB and AC be made in proportion to the forces, and the lines CD and DB be drawn parallel to them, so as to complete the parallelogram, then the line which the body A will describe will be the diagonal AD; and the length of this line will represent the force with which the body will move.

Example 1. There are many instances in nature of motion produced by several powers acting at the same time. A ship driven by the wind and tide is one: so also is a paper kite, acted upon by the wind in one direction, and by the string in another.

2. A body let fall from the top of a mast, when the vessel is in motion, will fall directly down the mast; because

the motion it had acquired carries it forward just as fast a the vessel moves: it describes a parabola.

Observation. Any body thrown obliquely into the ai describes a curve called a parabola. A body will go th greatest distance in a horizontal direction, when projecte at an elevation of forty-five degrees.

3. A ball fired from a cannon is acted upon by tw forces; the one is that occasioned by the powder, the other is the accelerating force of gravity; it therefore describe a curve called the parabola. This is the foundation of th art of gunnery.

43. *Accelerated* motion is that in which th velocity is continually increasing.

44. *Uniformly accelerated* motion, is that i which the velocity increases equally in equa times.

Example. The increasing velocity with which a bod falls to the earth, is an instance of accelerated motio which is caused by the constant action of gravity.

45. Motion is said to be *retarded,* if its velocity continually decreases; and to be *uniformly retarded,* if its volocity decreases equa ly in equal times.

46. The velocities of falling bodies are i proportion to the spaces run over.

47. The velocities, and also the spaces passed over by falling bodies, in each instant, increase as the odd numbers 1, 3, 5, 7, 9, &c.

Illustration. In the first instant there is one space ru through, in the second three, in the third five, in the fourt seven, and so on.

Observation. The sum of any *number* of the odd numbers 1, 3, 5, &c. is equal to the square of that number; that is $1+=2^2$; $1+3+5=3^2$; $1+3+5+7=4^2$, &c.

Corollary. It follows that the *whole* space described is as the square of the time; that is, in twice the time it will fall through four times the space; in thrice the time, nine times the space, &c.

Example. In the first instant there is one space run through; at the end of the second, there are four; at the end of the third, nine; and so on.

48. It is found by experiment, that a body falling from a height, moves at the rate of about 16 feet in the first second of time; in the next it moves 48, in the third 80, in the fourth 112 feet, and so on.*

Observation 1. To find the whole space a body will fall through, by the force of gravity, in any number of seconds, multiply the square of the number of seconds by 16 feet.

2. To find the velocity acquired, multiply twice 16 feet by the number of seconds it has been falling.

3. To find the time required to fall through any given space, divide the space in feet by 16, and extract the square root of the quotient for the time in seconds.

4. If a cannon ball were projected perpendicularly upwards, it would return to the earth with the same force with which it left the cannon.

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*All bodies, whether light or heavy, fall equally fast in a vacuum; and in this and the following articles there is supposed to be no resistance from the air.

49. The *force* with which a body moves, or which it would exert upon another body opposed to it, is always equal to its velocity multiplied by its weight.

50. This force is called the *momentum* of the body.

Illustration. If two equal bodies move with different velocities, their forces or momenta are in proportion to their velocities.

Experiment 1. If two equal cannon balls be projected by different quantities of powder, so that the velocity of the one is double that of the other, then the force or momentum of the former will be double that of the latter.

2. If two stones, one of two pounds and the other of six pounds, be hurled with equal velocities, the force or momentum of the latter will be three times as great as that of the former.

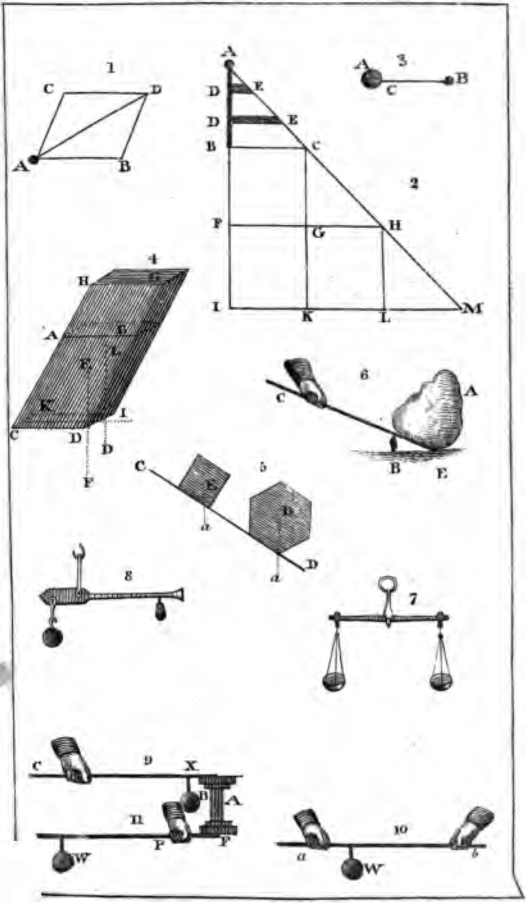
Corollary. In all cases, the momenta of bodies must be as the quantities of matter multiplied into the velocities.

CENTRAL FORCES, AND THE CENTRE OF GRAVITY.

51. All motion produced upon a body by one force only, must be in a right line.

Corollary. Therefore a body moving in a curvilinear direction must be acted upon by two forces at least; and when one of these ceases to act, the body will move again in a straight line.

Mechanics Pl. I.



Experiment. A stone in a sling is moved round by the hand, while it is pulled towards the centre of the circle which it describes by the string. But when the string is let loose, the stone flies off in a tangent to the circle.

52. Every body moved in a circle tends to fly off from the centre: this tendency is called the *centrifugal* force.

53. That force by which bodies are drawn towards a centre, and which makes them revolve in a circle, is called the *centripetal* force.

54. The centrifugal and centripetal forces are denominated *central* forces; and when a body revolves in a circular orbit, those two forces are equal.

55. The *centre of gravity* of a body is that point about which all its parts do in any situation exactly balance each other.

Observation 1. The centre of gravity of a circle, sphere, or any regular body, is its centre. The centre of gravity of a parallelogram, is at the intersection of its diagonals.

2. To find the centre of gravity of a triangle, draw lines from any two angles to bisect their opposite sides; and the point in which these lines intersect each other, will be the centre of gravity.

3. If a body be suspended from any point, the centre of gravity will be immediately below the point of suspension; hence, to find the centre of gravity of any body *mechanically*, suspend the body and a plumb line from any point, and mark the direction of the line on the body; then do the same from any other point, and the point in which these two lines cross each other will be the centre of gravity.

56. If a body be suspended or supported by the centre of gravity, it will rest in any position in which it is put.

57. Whatever supports the centre of gravity, bears the weight of the whole body; therefore the whole weight of a body may be considered as centred in this point.

58. The common centre of gravity of two or more bodies, is the point upon which they would rest in any position.

Illustration. If the centres of gravity of two bodies A, B, fig. 3, be connected by the right line AB, the distances AC, and BC, from the common centre of gravity C, are inversely as the weight of the bodies A and B; that is, the point C will be as much nearer to A than to B, as A is heavier than B; that is, AC: BC:: B: A.

Experiment. Suppose A to be a ball of 12 pounds, and B to weigh only 4 pounds, and the length AC to be 5 inches: then BC will be 15 inches; for it will be 5: BC: : 4: 12, or $4 \times BC = 5 \times 12 = 60$, and $BC = \frac{60}{4} = 15$.

59. If a line be drawn from the centre of gravity of a body perpendicular to the horizon, it is called the *line of direction*, because it is the line that the centre of gravity would describe, if the body were suffered to fall.

69. While the line of direction falls within the base upon which a body stands, the body cannot fall; but if it fall without the base, the *body will tumble.*

Illustration. The inclining body ABCD, fig. 4, whose centre of gravity is E, stands firmly, because the line of direction E F falls within the base. But if the body ABGH be placod upon it, the centre of gravity will be raised to L, and then the line of direction L D will fall out of the base; of course the centre of gravity is not supported, and the whole must fall.

Corollary. This shows the folly of rising up in a coach or boat in danger of oversetting, which raises the centre of gravity, and perhaps throws the line of direction out of the base. Whereas in such a situation the proper course is to slip to the bottom, which brings the line of direction, and consequently the centre of gravity farther within the base, and diminishes the danger.

61. The broader the base, and the nearer the line of direction is to the centre of it, the more firmly does a body stand.

62. The narrower the base of a body, and the nearer the line of direction is to the side of it, the more easily it is overthrown.

Corollary. Hence a sphere is easily rolled upon a horizontal plane; and a narrow pointed body is with difficulty made to stand.

63. If a plane be inclined on which a heavy body is placed, the body will slide down upon the plane while the line of direction falls within the base; but it will roll down, when that line falls without the base.

Illustration. The body E, fig. 5, having the line of direction Ea within the base, will only slide down; but the line of direction Ba of the body B falling out of the base, that body rolls down the plane.

Example 1. When the line of direction falls w the base of our feet, we stand; and most firmly, wh is in the middle; but when it is out of the base, we fal

2. Rope-dancers are able to perform their feat knowing how to keep the common centre of gravit themselves and their pole, just within the base.

3. We apply this principle in the common actior life: thus we bend our body forward when we rise fr chair, or go up stairs: a man leans forward when he ries a burthen on his back; and to the right or left, a carries it on the opposite side.

OF THE MECHANICAL POWERS.*

64. The *mechanical powers* are simple gines, that enable men to raise heavy weig move heavy bodies, and overcome resistan which they could not do with their natu strength alone.

65. Every machine is composed of one more of the mechanical powers.

66. Three things are always to be con ered in treating of mechanical engines: 1. T *weight* to be raised; 2. the *power* by whic is to be raised; and, 3. the *instrument* which this is to be effected.

67. There are six mechanical powers.

---

* *Mechanics* is the *science* of *motion*; hence *mechan* powers are machines to enable men to give motio *bodies.*

the *lever;* the *pulley;* the *wheel* and *axis;* the *inclined plane;* the *wedge;* and the *screw.*

Observation. The first three mechanical powers act upon the principle of the lever; the other three upon the principle of the inclined plane.

68. The power of a machine is calculated when it is in a state of equilibrium, that is when the *power* just balances the *resistance* of the weight.

Observation. In the use of all the mechanical powers, what is gained in power is lost in time.

OF THE LEVER.

69. The *lever* is a bar of iron or wood, supported on, and moveable round, a prop called a *fulcrum.*

70. There are three kinds of levers, distinguished according to the different situations of the fulcrum, and the power, with respect to each other.

71. In all kinds of levers, the power is to the weight, as the distance of the weight from the fulcrum, is to the distance of the power from the fulcrum.

72. In the lever of the first kind, the fulcrum is placed between the weight and the moving power, as in fig. 6.

Illustration. If it be required to raise the stone A, which weighs 1000 pounds, by the strength of a man equal to 100 pounds weight; a lever CE, which rests on the prop B, is placed with one end under the stone, and the man presses it down at the other end C. As the man's strength is on equal to the tenth part of the weight of the stone, the ar of the lever BC must be ten times as long as the arm B in order that the power and the weight may balance ea other.

Experiment 1. A *balance* is a lever of the first ki with equal arms. See fig. 7.

2. The steel-yard, fig. 8, is also the first kind of leve with a moveable weight.

3. A poker in the act of stirring the fire is a lever of th kind: the bar of the grate upon which it rests is the fi crum; the coals, the weight to be overcome; and the ha is the power.

4. To this kind of lever may be referred scissors, pi cers, snuffers, &c. which are made of two levers acti contrary to each other. The fulcrum, in these cases, b ing the pin which keeps them together.

73. The lever of the first kind is chief used for loosening large stones; or to rai great weights to small heights, in order get ropes under them.

74. In the second kind of lever, the fulcru is at one end, the power at the other, and t weight between them: see fig. 9, where A the fulcrum, B the weight, and C the powe

Illustration. The advantage gained by this lever is great as the distance of the power from the fulcrum excee the distance of the weight from it: thus, if the hand at be nine times as far from A as the point X on which t weight acts, then the force of one pound at C will balan the weight B of 9 lb.

Experiment 1. This kind of lever shows the reason w two men carrying a burthen, as a cask upon a pole, may bear unequal shares, according to their strength, by placing it nearer to the one than the other: see fig. 10. Here the weight W is three times as near *a* as to *b*, of course *a* would bear three times as much weight as *b*.

2. This is applicable to the cases of two horses of unequal strength, where the beam may be so divided, that the horses shall draw in proportion to their respective abilities.

3. To this kind of lever may be referred oars, rudders of ships, doors turning on hinges, cutting knives which are fixed at one end, &c.

75. In the lever of the third kind, the prop is at one end, the weight at the other, and the power applied between them. Here the power must exceed the weight, in the same proportion as the distance of the weight from the prop, exceeds the distance of the power from it.

Illustration. Let F, fig. 11, be the prop or fulcrum, P the power, and W the weight; if the distance P F be only three inches, and W F be 12, then for the hand P to balance the weight of 20 lb. it will require a force of 4 times 20, or 80lb., because the weight is at four times the distance from the fulcrum that the power is.

Experiment 1. A ladder, which is to be raised by the strength of a man's arms, represents a lever of this kind, where the fulcrum is that end which is fixed against the wall, or upon which another man stands; the weight may be considered as at the top of the ladder, and the power is the strength applied to the rearing of it.

2. The wheels in clock and watch work may be reckoned levers of this kind, because the power that moves them

acts near the *centre* of motion, by a pinion, and the resistance it has to overcome acts against the teeth at the *circumference.*

3. The bones of a man's arm, and the greatest number of the moveable bones of animals, are levers of the third kind. To take the arm, plate 2, fig. 12, as an instance D, the elbow is the centre of motion, the power is the muscle inserted at C, about one tenth part as far below the elbow as the hand is, and A is the weight to be raised; the muscle must accordingly exert a power equal to one hundred pounds, to raise a weight of ten pounds.

Corollary. Hence in natural levers the power is disadvantageously situated, owing to the power being so near the centre of motion; but the loss of power is compensated by the beauty and compactness of the limb.

76. What is called a hammer-lever, differs in nothing but its form, from a lever of the first kind.

Experiment 1. If the shaft of a hammer is six times as long as the iron part that draws the nail, a man will draw a nail with one sixth part of the power that he must use to pull it out with a pair of pincers; in the latter case, the nail would move as fast as the hand; but, in the former, the hand would move over six times as much space as the nail during the time of drawing it out of the wood.

Corollary. In all the mechanical powers it will be found, that the advantage gained is in proportion to the spaces passed over by the moving power and weight.

OF THE WHEEL AND AXIS.

77. The wheel and axis, though made in many forms, consists of a cylinder and a wheel fastened to it, as in fig. 14, or of a cylinder with projecting spokes, that answer the same purpose as a wheel, as in fig. 15.

78. The advantage gained is in proportion as the circumference of the wheel is greater than that of the axis; or, as the diameter of the wheel is greater than the diameter of the axis.

Illustration. If the diameter of the wheel, fig. 14, or the length of the spokes, fig. 15, be four feet, and the diameter of the axis only 8 inches, then the power, P, of one hundred pounds, or the strength of a man applied to the spokes, S, equivalent to a hundred pounds, will balance a weight, W, of six hundred pounds.

In this case, as in the lever, the power will travel over six times as much space as the weight, when the machine is put in motion.

Example 1. To this engine, cranes of all kinds for raising heavy weights may be referred.

2. Sometimes the axis is turned by a winch, fastened to it, which serves for a wheel, and the power gained is in proportion as the winch is larger than the axis.

3. A capstan is a cylinder of wood, with holes in it, into which bars are put to turn it round. The bars are made to act something like the spokes, fig. 15.

OF THE PULLEY.

79. The pulley is a small wheel turning c
an axis, with a rope passing over it. Se
fig. 16.

80. The small wheel x is called a sheev
and is so fixed to a block, as to be moveab
round a pin passing through the centre.

81. Pullies are either *fixed* or *moveable.*

82. The fixed pulley gives no mechanic
advantage, but is used only to change the d
rection of the power. By it a man ma
raise a weight to any height, as a stone to th
top of a building, without moving from th
place in which he is; otherwise he must as
cend with the weight.

83. The moveable pulley represented by
fig. 16. is fixed to the weight, and rises an
falls with it; and the advantage gained by
is as 2 to 1; that is, a power exerted by th
hand *h*, of ten pounds, will balance a weigh
W, of twenty pounds.

Illustration. The reason of this is evident; for, in raisin
the weight one inch, foot, or yard, both sides of the ro
must be shortened as much; that is, the hand *h* mu
move through two inches, feet, or yards; which shows, a
before, that the space through which the power move
must be always in proportion to the advantage gained.

84. When the upper fixed block Z, fig. 17

contains *two* pullies, which only turn on their axes, and the lower moveable block x contains also two, which turn and rise with the weight W, the advantage gained is as *four* to *one.*

Illustration. For each pulley in the lower block will be acted upon by an equal part of the weight, and since in each pulley that moves with the weight a double increase of power is gained, therefore the advantage gained is as *four to one.*

85. In general, the advantage gained by pullies is found by multiplying the number of pullies in the lower block by two.

Example 1. A weight W of 72 lbs. may be balanced with a set of pullies, having four in the lower block, by a power of nine pounds, because 72 divided by 8 gives 9; but in this case, the power, when put in motion, will pass over eight times as much space as the weight; that is, to raise the weight one foot, the hand must move over eight feet.

86. A pair of blocks with a rope is called a *tackle.*

OF THE INCLINED PLANE.

87. The mechanical power is merely a plane surface inclined to the horizon, and is used to move weights from one level to another, fig. 20.

88. It is often made by placing boards or earth, in a sloping direction, and is of great importance in rolling up heavy bodies, as casks, wheel-barrows heavy laden, &c.

89. The force with which a body descends upon an inclined plane, is to the force with which it would descend perpendicularly in free space, as the height of the plane is to its length.

Illustration. If a plane be inclined to the horizon as AD, fig. 20, and three times the length of the perpendicular D B, the cylinder E will be supported by a power equal to a third part of its weight.

2. If a plane be parallel to the horizon, a cylinder will be at rest on any part of it where it is laid.

3. If a plane be placed perpendicularly, a cylinder will descend with its whole weight, and would require a power equal to its weight to keep it from descending.

90. The advantage gained by this mechanical power, is in proportion as the length of the plane exceeds the perpendicular height.

Example. If the plane be 20 feet long, and the perpendicular height be 4 feet, then 500 lbs. would be balanced upon it by 100 lbs, because the plain is five times the length of the perpendicular height to which the weight is to be raised.

91. To the inclined plane may be reduced hatchets, chisels, and other edged tools, *which* are sloped only on one side.

Mechanics *Pl. II.*

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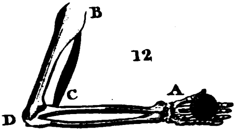

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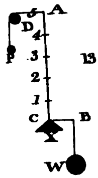

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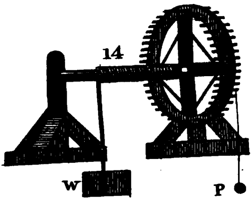

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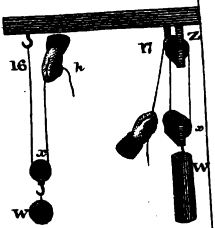

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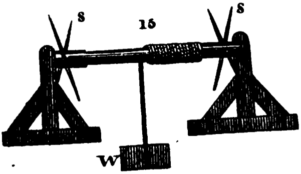

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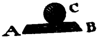

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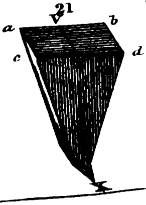

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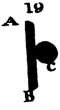

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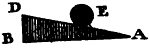

OF THE WEDGE.

92. The wedge may be considered as two equally inclined planes united at their bases.

93. The advantage gained is in proportion as the length of the two sides of the wedge is greater than the length of the back, or as the length of one side is greater than the length of half the back.

Illustration. The wedge *a b c d x* may be divided into two inclined planes, *a v c z x;* and *b v d z x*, which may be used separately, and will gain advantage as such, and, therefore, when united at *x z*, the advantage gained will be in the same proportion as when they were used in different parts.

94. When the wood cleaves at a distance before the wedge, the advantage gained is in proportion as one side of the cleft, is greater than half the length of the back.

95. The wedge is a very important mechanical power, used to split rocks, &c. which could not be effected by any of the other mechanical powers.

96. All instruments, as many sorts of chisels that are sloped on both sides, are to be referred to the principle of the wedge.

OF THE SCREW.

97. The screw is never used without the application of a lever or winch to assist in turning it; it then becomes a compound engine of very great force, either to press bodies closer together, or to raise great weights.

98. The screw may be conceived to be made, by cutting a piece of paper into the form of an inclined plane, and then wrapping it round a cylinder. The edge of the paper will form a spiral line round the cylinder, which will answer to the thread of the screw.

99. The advantage gained by this mechanical power, is in proportion as the circumference of the circle, made by the lever or winch, is greater than the distance between the threads of the screw.

Illustration. It is evident that the winch or lever must turn the cylinder once round, before the weight, or the resistance, can be moved from one spiral winding to another, as from x to x, see Plate III. fig. 22.

Example. If the distance of the spirals x x is half an inch, and the lever A three feet, or 36 inches long, then the circle described by the lever will be about 228 inches, or 456 half inches; consequently, a force at the end of the lever, equal to only one pound, would balance a resistance of 456 pounds.

Collorary. Hence it appears, that the longer the winch or lever, and the nearer the spirals, the more advantage is gained.

100. A screw may be moved upward or downward in a fixed nut, as in fig. 22, or the nut may move on the screw, as in fig. 23.

101. Almost all kinds of presses, common cork-screws, &c. act upon the principle of this mechanical power.

102. When a screw acts in a wheel, it is called an *endless* screw.

103. In the application of the mechanical powers, one-third must be allowed to overcome the frictions, and other obstacles, to which all machines are liable.

Example. If 60lbs. are required to balance any weight with a mechanical power, 80lbs. will be wanted to put the machine in motion.

Observation. Of the simple mechanical powers, the *lever* has much the least friction. In the *screw*, the friction is much greater, and greater still in the *wedge*. The friction may be diminished, either by the interposition of some oily substance, or by mechanical contrivances.

104. In all machines, the momentum of the moving power and weight must always be equal; hence, what is gained in power, is lost in time.

Example. If a man can raise by a single fixed pulley, a beam to the top of a house in two minutes, he will be able to raise six inch beams in 12 minutes: but with a tackle, having three lower pullies, he will raise six beams with the same ease at once; but he will be six times as long about it, that is, twelve minutes, because his hand will have six times as much space to pass over.

105. One capital advantage in the mechanical powers, is, that if the six beams were in one piece, it might be raised by a tackle, though it would be impossible to move it by the unassisted strength of a single man.

106. Another advantage is, that by machines we can give a more convenient direction to the moving power, and apply its action at some distance from the body to be moved.

OF THE MOVING POWERS.

107. The principal moving powers are, first, the strength of animals, chiefly that of men and horses; secondly, the force of running water and of wind; thirdly, the force of steam; fourthly, the force of springs; fifthly, the weight of heavy bodies.

108. The simple weight, as applied to clocks, jacks, and other machines, is the power which can be most easily applied as a first mover, and its action also is most uniform.

109. As this power requires to be renewed after a certain period, it is mostly used for slow movements.

110. The spring is a useful moving power, but, like the weight, it requires to be wound up after a certain time, whence it is also chiefly used for slow movements.

111. The spring differs from the weight in one remarkable respect, which is, that its action is never uniform, being strongest when most bent; but there are methods of rectifying this defect.

Example. Thus the chain of a watch is made to wind on a conical piece of metal, which assists the action of the spring when it is wanted.

112. The steam of boiling water is a most powerful agent, and recent improvements have extended the application of it from the smallest to the most powerful engines.

113. The force of running water, and that of wind, are very advantageous movers of many engines, such as pumps, mills, &c.

114. Running water is preferable to wind, as a mover of machines, on account of its uniformity.

115. As to the natural strength of living animals, it may be remarked, that a man of ordinary strength is reckoned capable of doing about one-fifth part as much work as a horse.

OF PENDULUMS.

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116. A pendulum is a heavy body hanging by a small string or wire, which is moveable round a centre.

Observation. The velocity or force acquired by a pendulum in moving through any distance to the lowest point, carries it the same distance on the other side of the lowest point.

117. Each swing that a pendulum makes is called a *vibration* or *oscillation.*

118. All the vibrations of the same pendulum, whether great or small, are performed in equal times.

119. The longer a pendulum, the slower are its vibrations.

120. A pendulum that vibrates in this country in a second of time, or that vibrates seconds, is a little more than thirty-nine inches long.

121. A pendulum to vibrate seconds, must be somewhat shorter at the equator than at the poles, or at any place between the equator and poles.

Illustration. The force of gravity at the earth's surface *continually* increases as we go from the equator towards *either pole,* which makes a body fall, or a pendulum vibrate faster. Hence a pendulum that would vibrate in a second of time at the equator, would vibrate in less than a second, if taken north or south of it.

122. A pendulum to vibrate half seconds, must be only one fourth part as long as one that vibrates seconds.

123. A pendulum to vibrate once in two seconds, must be four times as long as that which vibrates seconds.

124. The lengths of pendulums are to one another inversely as the squares of the number of vibrations in a given time.

Example. It is found by experiment, that a pendulum which vibrates 60 times in a minute is 39.13 inches nearly; therefore, to find how long pendulums must be that vibrate 30, 50, and 120 times in a minute, we say :—

					Inches.		*Inches.*
As	30^2	:	60^2	: :	39.13	:	156.52
	50^2	:	60^2	: :	39.13	:	56.34
	120^2	:	60^2	: :	39 13	:	9.78

125. As heat expands, and cold contracts all metals, a pendulum rod is longer in warm weather than in cold ; which is a chief cause of irregularity in clocks, a clock going faster in cold than in warm weather.

HYDROSTATICS, OR THE LAWS OF FLUIDS.

126. A fluid is a body, the parts of which are easily moved among each other.

127. Fluids are either non-elastic and incompressible, as water, oil, mercury, &c., or elastic and compressible, as air, steam, and the different gases.

Observation 1. Late experiments have shown that water, oil, mercury, &c. which were for a long time considered incompressible, are capable of being compressed in a very small degree. The compression of water, by a force equal to twice the weight of the atmosphere, or twenty-nine pounds on a square inch of surface, is about one part in eleven thousand. Water is found to be more compressible in *winter* than in summer.

2. The particles of fluids are believed by philosophers to be hard, round, and smooth; and that being round, there must be vacant spaces between them, similar to those between a collection of cannon balls. Water is capable of dissolving a considerable quantity of salt, sugar, &c. without increasing its bulk; the particles of the salt or sugar, being smaller than the particles of water, go between them, as bullets or shot between larger balls.

3. It is evident that the *weight* of the water is increased by the addition of salt, or sugar, &c. although the *bulk* is not; hence any quantity of salt water is heavier than an equal bulk of fresh, and consequently a ship, or any thing that floats on water, will not sink so deep in *salt water* as it will in *fresh*.

128. The science of hydrostatics treats of the mechanical properties of non-elastic fluids, particularly of water.

Hydrostatics &c Pl. III.

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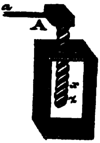

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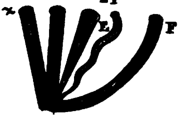

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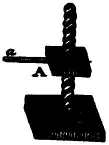

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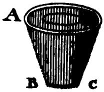

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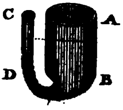

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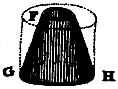

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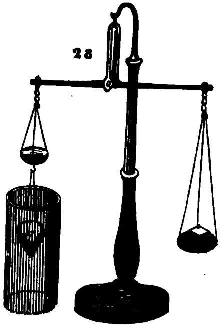

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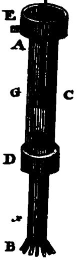

129. Fluids are subject to the same laws of gravity with solids; but their want of cohesion occasions some peculiarities.

130. The parts of a *solid* are so connected as to form a whole; and their effort is concentrated in a single point, called the centre of gravity; but the parts of a *fluid* gravitate independently of each other.

131. Fluids press not only like solids, perpendicularly, but also upwards, sideways, and in every direction equally.

Experiment. Take a glass tube, open at both ends; put a cork in one end, and immerse the other in water. The fluid will not rise far in the tube; but the moment the cork is taken out it will rise to a level with the surrounding water, which shows the pressure upwards.

132. A fluid kept in an open vessel will assume a surface, parallel to the horizon, and will remain at rest.

Experiment. If a vessel, fig. 24, consist of pipes variously inclined, communicating with each other at B, and open at the top, water poured into any one of them will rise to the same level in all.

The pressure of the same fluid is in proportion to the perpendicular height, and is exerted in every direction; so that all the parts, at the same depth, press each other with equal force in every direction.

Experiment 1. If a bladder full of air be immersed water, then the perpendicular pressure is manifest; the deeper the bladder is immersed, the more will its be contracted.

2. An empty bottle being corked, and by means of weight, let down to a certain depth into the sea, it will be broken, or the cork will be driven into it by the perpendicular pressure. But a bottle filled with water, wine, &c. may be let down to any depth, without damage; because, in this case, the internal pressure is equal to the external.

3. It is evident that the quantities of water in the different pipes, fig. 24, whatever be their size, press equall against each other; for if the water be suddenly taken ou of the pipes *E*, *z*, or *F*, the surface of the water will instantly descend to a lower level in all the other pipes.

134. The horizontal bottom of a vessel sustains the pressure of a column of the fluid, th base of which is the bottom of the vessel, an perpendicular height, the depth of the fluid.

Experiment 1. In the vessel AB, fig. 25, the bottom, CB does not sustain a pressure equal to the quantity of th whole fluid, but only of a column whose base is CB, an height CE.

2. In the vessel FG, fig. 26, the bottom sustains a pressure equal to what it would if the vessel were as wide the top as bottom.

135. The pressure of a fluid upon any give part of the bottom or sides of a vessel, is equa to the weight of a column of that fluid, havin a base equal to that part of the bottom or side and an altitude equal to the perpendicula height of the fluid above it.

Corollary. Hence may be calculated the pressure upon, and the strength required for, dams, cisterns, pipes, &c.

136. The hydrostatical paradox is this: that any quantity of fluid, however small, may be made to counterpoise any quantity, however large.

Experiment. If to the wide vessel AB, fig. 27, a tube C D be attached, and water be poured into either of them, it will stand at the same height in both; of course the small quantity in CD balances the large quantity in AB.

137. The upper pressure of fluids is shown by the hydrostatical bellows.

Illustration. This machine consists of two oval boards about 16 inches in length, and 14 in width, covered with leather, to rise and fall like the common bellows, but without valves. A pipe three feet long is fixed in the top board. Let a little water run into the bellows to separate the boards, then weights to the amount of two or three hundred pounds may be put on the upper board, after which, if the pipe be supplied with water, it will, by its upward pressure, sustain and lift up the weights.

OF SPECIFIC GRAVITIES.

138. By the *specific gravity* of a body is meant, its weight compared with the weight of an *equal bulk* of another given body.

139. It is usual to compare the weight of bodies with that of water, as it is by weighing

them in water that their specific gravities are found.

140. A body immersed in a fluid, will sink to the bottom, if it be heavier than its bulk of the fluid.

141. If a body be suspended in a fluid, it will lose as much of what it weighed in air, as its bulk of the fluid weighs.

Illustration. A cubic foot of water weighs 1000 ounces avoirdupois; hence a cubic foot of metal or of any other substance, when suspended in water, loses 1000 ounces of its weight.

142. All bodies of equal bulks, which would sink in fluids, lose equal weights when suspended therein; and unequal bodies lose in proportion to their bulks.

143. If upon a fluid, a body be placed which is specifically lighter than the fluid, it will sink till it has displaced a quantity of the fluid, the weight of which is equal to the weight of the body.

144. If the same body float successively on the surfaces of fluids of different specific gravities, it will displace different quantities of those fluids, in consequence of its sinking deeper in the lighter than in the heavier fluid.

145. If the weight of the body be equal to that of the same bulk of the fluid, then the body will remain at rest in any part of that fluid below the surface.

Pneumatics &c.

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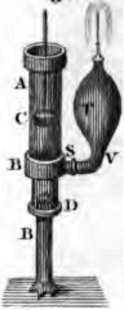
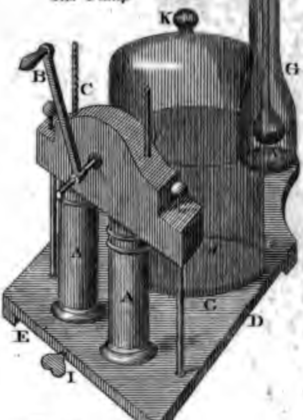


Air Pump 31



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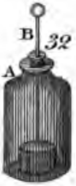

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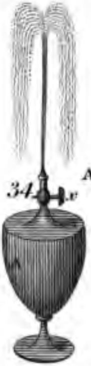

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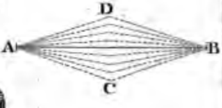

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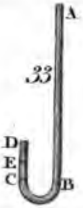

B. Tanner Sc.

146. If a body heavier than an equal bulk of a certain fluid, be placed on the surface of that fluid, it will sink to the bottom.

147. The *hydrostatic balance*, used for finding the specific gravities of bodies, differs but little from the common balance, see fig. 28; it has a hook at the bottom of one of the scales, on which one of the substances are to be examined may be hung by horse-hairs, so as to be immersed in a vessel of water without wetting the scale.

If a body *x*, fig. 28, suspended under the scale, be first counterpoised in air by weights in the opposite scale, and then immersed in water, the equilibrium will be destroyed; then if a weight be put into the scale from which the body hangs, to restore the equilibrium, that weight will be equal to the weight of a bulk of water as large as the immersed body. If the weight in the scale from which the body is suspended, be divided into the weight in the other scale, the quotient will be the specific gravity of the body.

148. The specific gravities of all bodies that sink in water may be found; first, by weighing the body in air, then in water, and dividing the weight in air by the loss in water.

Example. A guinea weighs 129 grains in air; by being weighed in water it loses 7 and one fourth grains, which shows that a quantity of water of equal bulk with the guinea weighs 7 and one-fourth grains: divide 129 by 7 and a quarter, or 7.25, and the quotient will be 17.793, which proves the guinea to be 17.793 times as heavy as its bulk of water.

149. The instrument used for compari the specific gravities of liquids, is called *hydrometer.*

HYDRAULICS.

150. The science of Hydraulics teach how to estimate the velocity and force fluids in motion.

151. Upon the principles of this scienc all machines worked by water are construc ed, as engines, mills, pumps, fountains, &c.

152. Fluids, by their pressure, may be co veyed over hills and valleys, in bended pipe to any height not greater than the level the source from whence they flow.

153. Upon this principle fountains a formed; for if near the bottom of any vesse a small pipe bending upwards be fastene the water will spout out through the pip and rise nearly as high as the surface of t water in the vessel.

154. The *common pump,* improperly calle the sucking pump, consists of a pipe, open both ends, in which is a moveable piston th fits the bore exactly.

Illustration. Fig. 29 is the representation of a co mon pump: AD is called the barrel, which contains t piston; BD the suction-pipe. At the junction of the two parts there is fixed a valve D, opening upwards. The mode of operation is as follows: the part B is fixed in water, and the piston C is to be close down upon the valve D. In drawing up the piston from D to C, a vacuum is formed in that part, consequently the air in the rest of the pipe will force its way through the valve D, and fill the part which had been exhausted; but it will be rarer than before, and not being equivalent to the pressure of the atmosphere upon the water in which the pump is immersed, the water will be forced up into the suction-pipe as far as *x*, until the air within be as dense as before. Upon depressing the piston a second time, the same effect is produced, till at length the water itself forces its way into the barrel. When the piston now descends, it is forced through the water, which cannot repass through D, it must therefore get above the piston by passing through its valve G, and when it is next raised, all the water above it will be lifted up, and will run off by the pipe E.

155. The *forcing pump* consists of a barrel, a plunger, and two fixed valves, that should be air-tight, and so disposed, as to let the water freely rise, but absolutely to hinder its return.

Illustration. In fig. 30, AB is the barrel, C a solid piston or forcer, at D is one valve opening upwards, the other is in the branching pipe S. When the forcer is first moved upwards in the barrel, the air below will be rarified, and the water rise up in B: by repeated strokes of the piston the water will be brought up between the fixed valves D and S. When the piston C is forced down, the water cannot descend by D, but must make its way through the upper valve at S, which shuts the moment the water has passed V. is a strong air vessel closed at the top by a small pipe T, that reaches nearly to the bottom. The water is forced along the rising pipe S, gets into the vessel, and rises above the lower part of the pipe T. The air which is above the water in the vessel being confined, and condensed into a smaller than its natural space, presses by its elasticity upon the surface of the water, and forces it up the p T in a continued stream. This is the principle of the gine for extinguishing fires.

156. The water in the common pump ri in the suction-pipe by the pressure of the mosphere, upon the water around the pi This pressure is only capable of supportin column of water 33 feet high. Hence, t greatest elevation of the moveable piston, m never exceed 33 feet from the surface of t water in the well. *The piston*-rod, howev may be of any required length; but the hig the discharging pipe, or *nozzle* of the pump over 33 feet from the surface of the wat the harder the pump will work.

157. The forcing pump is unlimited in gard to the height to which it can raise wat

158. The air-vessel is added to the forci pump to give the water a more equable strea

159. A constant stream may be produc by *two* barrels, with pistons moving up a down alternately.

160. A bent tube, open at both ends, w one leg longer than the other, is called a *phon* or *crane*, and is frequently used for canting fluids from one vessel into anothe

Illustration 1. The syphon is used by immersing shorter end in the fluid to be decanted, and then apply the mouth to the longer end, and sucking out the air; fluid will immediately follow, and continue to flow, by pressure of the atmosphere and gravity. Or it ma used by first filling it, and, whilst full, immersing the s *er end in the* fluid, which will flow as before.

2. It is immaterial whether the legs be of the same size, or whether they be bent in various directions, provided the perpendicular altitude of the discharging leg be greater than that of the other.

3. The syphon cannot act, when the perpendicular altitude of the shorter leg above the surface of the fluid is greater than about 32 feet.

PNEUMATICS.

161. The science of pneumatics treats of the mechanical properties of elastic, or aeriform fluids; such as their *weight*, *density*, *compressibility* and *elasticity*.

162. The air in which we live surrounds the earth, and extends to a considerable height above it.

163. The air, together with the clouds and vapours that float in it, is called the atmosphere.

Observation. The air is principally composed of oxygen and nitrogen gases, in the proportion of about 21 parts of oxygen, by measure, to 79 of nitrogen, in 100. The oxygen of the atmosphere is necessary to animal and vegetable life, and also to combustion.

164. The air is not visible, because it is transparent.

Experiment 1. The existence of the air may be ascertained by swinging the hand swiftly up and down, which gives the idea of separating some resisting medium.

2. Any swift motion, as of a stick, whip, or fan, proves the existence of air as a resisting medium.

3. Take a glass vessel, turn the open part down, and holding it in that position, immerse it in water; then, if the glass be inclined a little, a bubble of air will go out, and an equal bulk of water take its place. If the glass be sufficiently inclined, all the air will escape, and the glass be entirely filled with water. Keeping the glass with the aperture down, it will remain full of water when drawn up, till the aperture is even with the surface of the water.

165. The air being a heavy body, presses, like other fluids, in every direction, upon whatever is immersed in it, and in proportion to the depths.

Example 1. It is known that the pressure of the atmosphere is less upon a high mountain, than in the plain or valley beneath.

2. The pressure of the air may be thus shown:—cover a wine glass, completely filled with water or wine, with a piece of writing paper; then place the palm of the hand over the paper, so as to hold it tight, and accurately even. The glass may then be turned upside down, and the hand removed, without the water running out. The pressure of the air upon the paper sustains the weight of water.

166. The air can be compressed into a much less space than it naturally occupies.

Experiment 1. Take a glass tube, open only at one end —it is of course full of air; plunge the open end into a bowl of water, and the water will rise an inch or so in the tube: the air, therefore, which before filled the whole length of the tube, is compressed into a smaller space.

2. Let a small cork swim on a basin of water, and cover it with an empty glass tumbler, which force down through the water; the cork will evidently show, that the surface of the water within the tumbler is not on a level with the surface without. This experiment proves, that air is a body that prevents water from occupying the same space with itself. It proves also that the air is compressible; because the water does ascend to a small height in the glass.

3. Upon this principle, the *diving bell* is constructed, by which persons are enabled to descend into the ocean and bring up what is valuable from the wreck of a vessel, &c. It is formed in the shape of a bell, with the large part below; and is made to descend vertically, by weights attached to it. The air in the upper part of the bell keeps out the water; and persons can breathe there with safety. Fresh air is supplied by letting it down in casks, or by a forcing air pump at the surface of the water. *Divers*, in coral and pearl fishing, and in taking goods from wrecks, often remain under water for several hours at a time.

167. The air is of an elastic, or springy nature, and the force of its spring is equal to its weight.

Experiment 1. A bladder filled with air by blowing into it, is highly elastic; it proves also that air is as much a substance as wood or metal, for no force without breaking the bladder, can bring the sides together, though the parts of an empty bladder may be squeezed into any shape.

2. Open a pair of common bellows, in the usual manner, and then stop the nozzle securely, and no power can bring the parts together, without first unstopping the nozzle or bursting the leather: another proof that the air is a solid substance.

168. By removing the pressure from air, it always expands, and it is not known to what degree this expansion will reach.

169. When air is in motion, it constitutes *wind*, which is nothing more than a current of air, varying in its force, according to the velocity with which it flows.

Observation 1. Heat and cold are by far the most general causes which are productive of wind. When the air becomes heated in any place, the surrounding colder air, which is heavier, rushes in and produces *wind*.

2. Also when the air is cooled in any place, as by the fall of rain from a thunder cloud, the column of cooled air, being heavier than the surrounding warmer air, rushes out in every direction. This is the reason why the wind always comes from a thunder cloud when it gets near, let us be on what side we may.

3. The sun and moon also produce wind, by occasioning a tide in the *atmosphere*, similar to that in the ocean.

4. The *trade wind* is a continual easterly wind that blows between the tropics.

5. The *monsoons* are winds, which in some parts of the Indian ocean, blow one half of the year in one direction, and the other half in the other.

170. Air pumps are machines for exhausting the air from certain vessels adapted to th purpose.

Illustration. Fig. 31 represents one of the most co venient air pumps. Its structure is very similar to that the common pump. A, A, are two brass barrels, each c taining a fixed valve near the bottom, opening upwai and a moveable piston attached to the lower end of racks C, c, with a valve also opening upwards. The pistons are moved by a wheel with cogs, working in the racks C, c, and turned by the winch B, which moves them up and down alternately. On the wooden frame DE there is a brass plate G, ground perfectly flat, and also a brass tube communicating with the two cylinders, and the cock I, and opening into the centre of the brass plate at *a*. K, the glass receiver to be exhausted of air, is made to fit very accurately on the brass plate. Having shut the cock I, the winch B is turned, which elevates one of the pistons as C, and thereby removes the pressure from the fixed valve in that barrel. The pressure being removed, the air in the receiver, by its expansive force, raises the fixed valve, and fills the space between the fixed valve and the piston. The winch B being then turned the other way, raises the piston *c*, and forces the piston C down; and as the fixed valve opens upwards, the air between it and the piston C, cannot pass again into the receiver, but forces up the valve in the piston and escapes. This process being continued by successively turning the winch B, the air is gradually exhausted from the receiver, which will become immovably fixed by the pressure of the superincumbent atmosphere. Upon opening the cock I, the air rushes violently, and with a noise, into the receiver.

Observation. As the fixed valve is raised by the expansive force of the air *in* the receiver, it is evident that all the air cannot be exhausted from a receiver by means of an air-pump.

171. Air is about 900 times as light as water.

Example. A quart of air may be weighed in a Florence flask to which a little apparatus is added, and it is found to weigh 16 grains; but a quart of water weighs 14621 grains: the latter number being divided by the former gives 914, so that the air is 914 times as light as water. The weight of the air is variable.

172. When the surface of a fluid, as water, quicksilver, &c. is exposed to the air, it is pressed by the atmosphere equally on every part, and is at rest.

173. If the pressure be removed from any part, the fluid, in that part, must yield and be forced out of its situation.

The following experiments show what the pressure of the air amounts to:

Experiment 1. Into the receiver A, fig. 32, put a small vessel of quicksilver x, and through the collar of leather, as at B, suspend a glass tube, closed at the upper end, over the quicksilver. The apparatus thus situated is to be placed on the brass plate of the air-pump, and the air completely exhausted from the receiver, the tube is then to be let down into the quicksilver, which will not rise in it as long as the receiver continues empty; but as soon as the air is re-admitted, all the surface of the quicksilver is pressed upon by the air, except that portion which lies above the orifice of the tube: it will therefore rise in the tube, until the weight of the elevated quicksilver presses as forcibly on that part of it which lies beneath the tube, as the weight of the air does on every other equal portion without the tube.

2. Take a syringe or common water squirt, and having pushed the piston to the farthest end, immerse it in water, then draw up the piston and the water will follow: for when the piston is raised, the air is drawn out of the syringe, and the pressure of the atmosphere is removed from the part of the water immediately under it; consequently the water yields in that part to the pressure on the surface.

3. Upon this principle *sucking pumps*, as they are called, act: the piston accurately fitting the inside of the barrel, by being raised, removes the pressure of the atmosphere

from that part, and consequently the water is forced up by the pressure upon the surface.

174. The pressure of the atmosphere is capable of supporting about 33 feet of water, or about 29 or 30 inches of quicksilver.

Observation. The pressure of the air, at the surface of the earth, is about 14 1-2 lbs. on every square inch. The pressure on a middle sized man (reckoning the surface at 12 square feet) is 25056 lbs. or more than eleven tons.

175. If a glass tube, upwards of thirty-one inches long, be filled with quicksilver, and have its aperture immersed in a basin of the same fluid, the altitude of the mercury in the tube will be found to vary both at different times and in different places.

176. Hence it appears that the weight of the atmosphere is variable, and the above mentioned tube filled with quicksilver, has, from its showing the actual weight of the atmosphere, been called *a barometer.*

Observation. The vacuum formed in the upper part of the barometer tube, is called the Torricellian vacuum, and is as perfect a vacuum as can be formed. It has its name from its discoverer, Torricelli, an Italian, who also first discovered the weight and pressure of air.

177. The most usual altitude of the barometer, in London, is between 28 and 31 inches, but it is seldom to be seen below 28½, or above 30½ inches.

Observation. Within the tropics, the altitude of the barometer varies much less than it does in more northern or southern places.

178. In calm weather, when the air is inclined to rain, the mercury is commonly low. In serene settled weather the mercury is generally high. During very great winds, though unaccompanied with rain, the mercury sinks lowest of all.

179. By increasing the pressure upon air, it may be condensed into any given space however small. The density of the air is in proportion to the force that compresses it.

Experiment. The bent tube A B C D, fig. 33, is open at both ends. Pour mercury in so as to rise in both sides of the tube to C and B; the part from C to D is full of air at the common density: stop up D so as to make it air tight, and pour mercury into A, so that the column of mercury A B shall be equal in length to the height at which it stands in the barometer at the time. The air in the shorter leg will now be compressed by the weight of the atmosphere, and also with an additional weight of a column of mercury. The mercury now in the shorter leg will be risen to E, and D E is only the half of D C: that is, the pressure of a double atmosphere compresses the air to half the space which it naturally occupies. If another column of mercury were added to the length A B, the air in D C would be reduced into one-third the space that it formerly occupied.

180. As all the parts of the atmosphere press upon each other, the air near the surface of the earth is denser than that which is at *some height* above it.

Observation 1. It is computed that the air, at 7 miles above the surface, is 1-4 as dense as at the surface; at 14 miles 1-16; at 21 miles 1-64, &c., taking the altitudes in *arithmetical progression:* the density of the air decreases in a *geometrical progression.*

2. Upon this principle the altitudes of mountains, &c. have been calculated by means of a barometer; but so many corrections are necessary in determining altitudes by a barometer, and the law of decrease in the density of the atmosphere not being fully established, results obtained in this way are only to be considered as approximations.

181. The height to which the atmosphere extends has never been exactly ascertained; but at a greater height than 45 miles it will not refract the rays of light from the sun.

MISCELLANEOUS EXPERIMENTS WITH THE AIR PUMP.

Experiment 1. If the air be exhausted from a glass receiver, the receiver will be held fast by the external pressure of the air.

2. If a small receiver be placed under a large one, and the air be exhausted from both, the large one will be held fast, while the small one may be easily moved; if the air be admitted into the large one, the small one will be held fast, while the large one will be loose.

3. If the hand be placed upon an open vessel, so as to close its upper orifice, and the air be exhausted from the vessel, the hand will be held down with considerable force.

If a piece of bladder cover the orifice instead of the hand, it will be broken by the pressure.

4. If a string be attached to the middle of a circular piece of wet leather, and the leather be pressed close on a smooth surface, by pulling the string perpendicularly, a partial vacuum is formed between the leather and surface, and thus a weight of several pounds may be raised, the pressure of the air preventing the leather from separating from the surface.

Observation. In this way the sea polypus, the limpet, and also various insects adhere to surfaces.

5. The operations of sucking, cupping, &c. are performed by the rarefication of the air in one part, whilst it presses on the adjacent parts. None of these operations could take place in vacuo.

6. The resistance of air to falling bodies is shown by exhausting a tall glass receiver of its air, and in that state the lightest body, as a feather, will fall to the bottom as soon as the heaviest metal. This is called the guinea and feather experiment.

7. If a cup of porous wood containing mercury be placed on the receiver of an air-pump, and the air from below be exhausted, the external pressure of the atmosphere will force the mercury through the wood in a sort of shower.

8. If two brass hemispheres of three or four inches in diameter, made for the purpose, be put together, and the internal air be exhausted, the pressure from without will require 150 lbs. to separate them: but if the external air be taken away, they will separate of themselves.

9. Take a square phial with a small valve at top, put it under the glass receiver of the air pump, and exhaust the air out of the receiver, then the air will escape from the phial at the same time. The air, now being suddenly admitted into the receiver, will break the phial, because the valve prevents it from getting into the phial again.

10. The elasticity or spring of air is shown by tying up a very small quantity of it in a bladder, and putting it under the receiver: the receiver is then to be exhausted of air, and the little air confined in the bladder, will, by its elasticity, completely fill the bladder.

11. Take a square phial full of air, with the cork accurately cemented in, so that no air can escape. Put it under the receiver, and exhaust the air from the receiver; the air within not being balanced by any without, will burst the bottle in pieces by its expansive force.

12. Put a shrivelled apple under the receiver, and exhaust the air; then the air within the apple will make it as plump and handsome as when it was first gathered; but by the admission of the air, it will return to its shrivelled state again.

13. If a fresh egg with the small end cut off be put in a glass under the receiver, and the air taken away, the small bubble of air contained in the large end of the egg will expand, and force the contents of the egg from the shell.

14. Some beer made warm, and put under the receiver, will appear to boil when the air is nearly exhausted from the glass.

15. The smoke of a candle will ascend in the air, but in an exhausted receiver it will fall to the bottom, which shows that it ascends because it is lighter than air. The heavier or denser the air is, the faster and more perpendicular the smoke rises.

16. The sound of a small bell may be heard while it is under a receiver full of air; but as soon as the air is exhausted, there will be no sound.

Cor. Hence air is necessary to the propagation of sound.

17. Animals will not live, nor candles burn, in an exhausted receiver.

18. A, fig. 34, is a strong copper vessel, having a tube that screws into the neck of it, so as to be air-tight, and so long as nearly to reach the bottom; x is the handle of a stop-cock. Having poured some water into the vessel, and screwed in the tube, the condensing syringe is to be adapted and the air condensed. The stop-cock is to be shut while the syringe is unscrewed; then, on opening the cock, the air, by its great density acting upon the water in the vessel, will force it out into a jet of considerable height. This is called the artificial fountain. The experiment will be the same, if the pipe is under an exhausted receiver, while the water in the vessel is exposed to the common pressure of the atmosphere.

19. The sound of a bell is much louder in condensed than in common air.

20. A square phial that would bear the pressure of the common atmosphere, may be broken by condensing the air around it.

OF ACOUSTICS.

182. Acoustics is the science which treats of sound in general; Diacoustics, of refracted sound; and Catacoustics, of reflected sound.

183. A sonorous body, whilst sounding, is unquestionably in a state of *vibration*, and the air, by similar vibrations, communicates and propagates these vibrations.

Observation. Sounding bodies produce *vibrations* or *concentric* waves in the air, like those on the surface of water, when any body is thrown into it.

184. There are three principal causes of the variety of sounds: first, the greater or less frequency of the vibration of sonorous bodies; secondly, the quantity of force of the vibrating particles; and, thirdly, the greater or less simplicity of the sounds. Hence are derived the height, strength, and quality of sounds.

185. The vibrations of a sounding body continue for a longer or shorter time, according as the body is more or less elastic, or as it is thicker or thinner.

Example. When a string of uniform shape and quality is stretched between, and fixed to two steady pins, as A B, fig. 35, if it be drawn out of its natural or quiescent position A B, into the situation A C B, and if then it be let go, it will, in consequence of its elasticity, not only come back to its position A B, but it will go beyond it, to the situation A D B, which is nearly as far from A B, as A C B was on the other side, and all this motion one way is called one vibration; after this, the string will go again nearly as far as C, making a second vibration, then nearly as far as D, making a third vibration, and so on; diminishing the extent of its vibrations gradually, until it settles in its original position A B.

186. The vibrations of a musical string are also communicated to other parts of it, which, at first sight, might be supposed to be at rest.

Example. If you divide a string as A D, fig. 36, into three equal parts, AB, BC, CD, by placing dots at C and

; place a bridge, like a violin bridge, at B, also place ight bodies, such as small bits of paper, at C, and at other places of the string B D; then draw a violin bow over the part AB; you will find that all the bits of paper will be thrown off from the part BD, excepting the one at C; showing that the point C remains at rest, whilst the remainder of the string is vibrating.

187. Sound is propagated successively from a sounding body, first to the places nearest to it, then to those more remote, &c.

188. In general, sound travels through the atmospheric air at the rate of 1142 feet per second, or one mile in less than five seconds.

189. The velocity of sound is the same, whether it be high or low, strong or feeble. A whisper flies as fast as thunder.

190. The velocity of sound is sensibly altered by winds. In the direction the wind is blowing, it goes *faster;* in the contrary direction, *slower.*

191. The knowledge of the velocity of sound may be applied to the measurement of distances, when no better method can conveniently be used.

Experiment. If 30 seconds elapse between seeing a flash of lightning and hearing the thunder, it would be know to be at the distance of about 6½ miles.

192. Air is the most common mediu through which sounds are transmitted; t sounds may also be conveyed by other bodi

both fluid and solid, as water, metal, wood, ropes, &c.

Experiment 1. If a person stop one of his ears with his finger, and press the other one against the end of a long stick or piece of timber, while a watch is applied to the other end, he will hear the beating of the watch very distinctly.

2. If a piece of metal, as a shovel, be tied to the middle of a woollen or flannel string, the two ends of which are pressed in a person's ears, while the metal is kept pendant before him, upon striking the metal, a sound similar to that of a large bell will be heard.

3. If a person stop both his ears, and place his teeth or temple against a watch, he will hear the beating distinctly.

4. The practice of placing the ear to the ground, in order to perceive the approach of horses or men, has been observed even amongst uncivilized nations.

5. Over a surface of water, the human voice has been heard 10 miles, and cannon 200 miles. Sound flies much farther over a smooth surface.

193. Sounds are also reflected by hard bodies; and this reflection produces the well known phenomenon called *echo.*

Experiment 1. If a person stand before a high wall or bank, and utter a word or make a noise, he will hear a repetition of it. The same effect is produced by a hill or a wood.

2. The distance of a wall or bank, may be calculated by noticing the time the sound is in going and returning.

Example. If the sound is 6 seconds going and returning, it is three seconds going. Hence the object against which it strikes, is 3 times 1142 feet distant.

194. As sound is reflected from surfaces, it may be collected in one place. Upon this principle whispering galleries are constructed.

Observation. If sound strikes a surface obliquely, it will go off obliquely in an opposite direction.

195. Sounds may be conveyed a much greater distance through tubes, than through the open air.

OPTICS.

196. *Light* consists of an inconceivably great number of particles, flowing from a luminous body in all manner of directions, and which, entering our eyes, produce the perception of the luminous body. By a *ray* of light is meant the motion of a single particle.

Observation. By a *luminous body* is meant any body that we can see, whether it be visible by the emission of *original* light like the sun, the stars, a candle, &c. or by *reflected* light, as the moon, the planets, a tree, &c.

Example. The light of a candle, if there be nothing to obstruct the passage, will fill the whole space within a mile of the candle, every way, with luminous particles, *before it has lost* the least sensible part of its substance.

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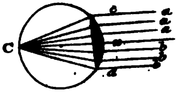

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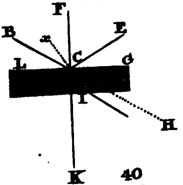

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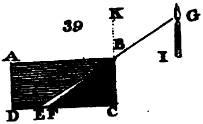

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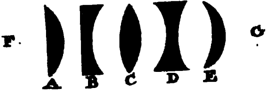

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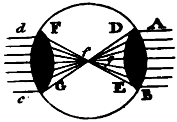

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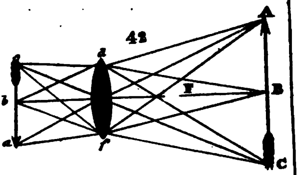

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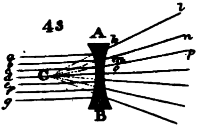

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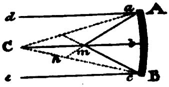

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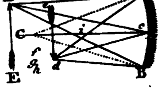

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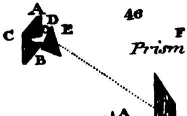

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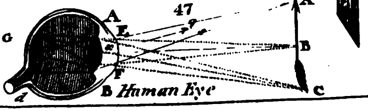

197. Light travels from the sun to the earth in about eight minutes, that is, at the rate of nearly two hundred thousand miles in a second of time.

198. The particles of light must be incomprehensibly small, for its rays cross each other in all possible directions without the least disturbance.

Experiment 1. Take a piece of brown paper and make a pin-hole in it; through this small aperture, a great variety of objects may be seen, as trees, houses, &c. The light proceeding from all these objects must pass at the same instant through the hole, and cross each other before they reach the eye, yet the clearness of vision is not disturbed by it.

2. Make a pin-hole in a piece of black paper, and hold it in an upright position before a row of candles; then on the wall, which must be at a little distance from the paper, some of the rays which flow from all the candles through the hole in the paper will form as many specks of light on the wall as there are candles, each speck being as clear and distinct as if there was only a single speck from one candle.

199. The particles flowing from a luminous body, as the sun, or a candle, and falling upon our eyes, give us the idea of light.

200. The rays of light falling on bodies, and reflected to our eyes, give us the idea of those bodies.

Experiment. Go into a dark room, and you have not the smallest conception of the several articles of furniture that it contains; admit the rays of light, these at the same instant (owing to the great swiftness with which they travel) fall upon the bodies in the room and are reflected to the eye, thereby exciting in our minds the idea of these bodies.

201. The impression made by light upon the eye, continues for some time after that which caused it is removed.

Illustration 1. If a live coal attached to one end of a stick, be made to revolve swiftly, there appears to be an uninterrupted circle of light, which shows that the impression continues, so as to make the body appear to be where it is not. The duration of the impression is longer or shorter, according as the body is more or less luminous.

2. When a person looks for some time at the sun, a lamp, or a bright window, the image will remain for some time.

3. The impression made by a bright object, is not sensibly diminished in one tenth of a second; hence, as light moves 200,000 miles in a second, the particles may be twenty thousand miles apart, and yet preserve an uninterrupted vision.

202. Every point of a visible body reflects the rays of light in all manner of directions.

Corollary. Hence every part of a surface of a body which is towards a spectator will be visible to him, when no intervening object stops the passage of light.

203. The rays of light always move in straight lines.

Experiment 1. No object can be seen through the bore of a bended pipe.

2. The shadows of bodies show that light proceeds in straight lines.

204. A parcel of rays of light proceeding from a point is called a *pencil of rays.*

105. A *medium* is any transparent body which suffers the rays of light to pass through it. Thus a vacuum, water, air, and glass, are *media.*

206. Bodies which do not admit the rays of light to pass through them, are called *opaque* bodies, as iron, wood, &c.

207. Parallel rays are such as move always at the same distance from each other.

208. If rays continually recede from each other, as from C to *c*, *d*, fig. 37, they are said to *diverge.*

209. If they continually approach each other, as in moving from *c, d* to C, they are said to *converge.*

210. The point from which diverging rays proceed is called the *radiant point.*

211. The point at which converging rays meet is called the *focus.*

212. The point towards which they tend, but which they are prevented from reaching by some obstacle, is called the *imaginary focus.*

213. While the rays of light continue in any medium of a uniform density, they move in straight lines.

214. If rays of light pass from one medium to another in a *perpendicular* direction, they

proceed through this medium in the same direction as before.

Experiment. If FC,* fig. 30, be a ray of light passing from air into water, it will continue on to K.

OF REFRACTION.

215. When rays of light pass *obliquely* out of one medium into another, which is either more dense or more rare, they are bent out of their former course, and are then said to be *refracted.*

216. Rays of light, in passing obliquely from a *rarer* into a *denser* medium, are always refracted *towards* a perpendicular to the refracting surface; and this refraction is more or less, according as the rays of light fall more or less obliquely on the refracting surface.

Experiment. Let BC, fig. 38, be supposed to be a ray of light passing out of air into water or glass, LG, at the point C; FCK is a line drawn perpendicular to LG, and the ray BC, instead of proceeding along CH, will be bent towards the perpendicular CK, as along CI.

217. When rays of light, proceeding from a heavenly body, enter the atmosphere, since they pass from a rarer into a denser medium, they are refracted towards a perpendicular, and appear as if they came from a higher point.

Corollary 1. Hence, as bodies always appear in the direction the light is proceeding from, when it enters our eyes, the sun, moon, stars, &c. *appear* to be higher than they really are. The refraction by the atmosphere increases the apparent altitude of all the heavenly bodies.

2. On this principle, we see the sun and other heavenly bodies, when they are actually below the horizon.

218. The nearer the body is to the horizon, the greater is the refraction by the atmosphere.

Observation 1. The oval appearance of the sun and moon, when near the horizon, is owing to the lower part being refracted or elevated more than the upper, by being nearer the horizon, which shortens the vertical diameter, while the horizontal diameter remains unchanged.

2. When a body *appears* to be in the horizon, the refraction is about 33′; when in the zenith, it is nothing.

219. When light passes out of a denser into a *rarer* medium, it moves in a direction *farther from* the perpendicular.

Experiment 1. Thus if the ray CI, fig. 38, pass out of a glass into air, it will not proceed in C*x*, but in the direction CB, farther from FC than C*x*.

2. Take a pan, ABCD, fig. 39, with an upright side, into a dark room; let in, by means of a small hole in the window shutter, a ray of light, GB, so as to fall upon the bottom of the pan at E; mark the spot E; then, without moving the pan, fill it with water, and the ray will now not pass on to E, but will be refracted to F. The candle, G, will answer as well as the direct rays of the sun.

3. If a shilling be stuck on the part F with wax, so that an eye at C cannot see it when the pan is empty, it

will become visible the moment the vessel is filled with w ter.

4. Take a glass goblet half full of water, and put a sh ling into it, then put a saucer or plate upon it, and holdi it tight on, turn plate and glass together; a bystander, u acquainted with the laws of refraction, will suppose th he sees a shilling and a half crown: the one is seen by fraction through the water, the other by the rays af refraction at the surface.

220. When rays of light proceed from th bottom of a vessel of water, since they pa from a denser to a rarer medium, they are r fracted *farther* from a perpendicular.

Corollary 1. Hence the bottom of a vessel or stream water, or any thing, as a fish, in the water, appears nea the surface than it really is; and the nearer the eye is a level with the surface of the water, the nearer does t object appear to the surface.

2. A stream of water is deeper than it appears to be.

Observation 1. The power of refraction is sometin greater in one body than in another of the same densi *Generally*, however, a denser body refracts more than rarer one. Glass refracts more than water; water, mo than air; and denser air, more than rarer air.

2. As the air increases in density towards the surface the earth, the rays of light, in passing through the atm phere, describe curves concave to the earth's surface.

221. A *lens* is a glass ground into such form as to collect or disperse the rays light which pass through it.

222. There are various kinds of lense named according to their forms.

223. A *plano-convex* lens has one side flat and the other convex, as A, fig. 40.

224. A *plano-concave* lens is flat on one side, and concave on the other, as B.

225. A *double convex* lens is convex on both sides, as C.

226. A *double concave* lens is concave on both sides, as D.

227. A *meniscus* is convex on one side and concave on the other, as E.

228. The *axis* of a lens is a line passing through the centre: thus FG is the axis to all the five lenses.

229. If parallel rays fall upon a plano-convex lens, they will be so refracted as to unite in a point behind, called the *principal focus*, or *focus of parallel rays.*

Example. Thus the rays *ab*, fig. 37, falling upon *cd*, are refracted towards the perpendicular C*x*, and unite in C.

230. The distance from the middle of the glass to the focus is called the *focal distance.*

231. The focal distance of a plano convex lens, is equal to the diameter of the sphere of which the lens is a portion.

232. The focal distance of a double convex lens is equal to the radious of a sphere of which the lens is a portion; see fig. 41.

233. All the rays of the sun which pass through a convex glass are collected in its focus,

234. The force of the heat at the focus is to the common heat of the sun, as the area of the glass is to the area of the focus.

Illustration. If a lens four inches in diameter collect the suns' rays into a focus at the distance of 12 inches, the image will not be more than one-tenth of an inch in diameter, the surface of this little circle is 1600 times less than the surface of the lens, and consequently the heat will be 1600 times greater at the focus than at the lens.

Cor. 1. Hence the construction of common burning glasses, which are all double convex lenses.

2. Hence the reason why furniture has been set on fire by leaving a globular decanter of water incautiously exposed to the rays of the sun; which acts as a double convex lens.

Observation 1. The heat at the focus of a lens, three feet in diameter, has been found sufficient to melt gold.

2. A black body is much more easily set on fire with a lens than a white one, because it does not reflect so many rays.

235. If another double convex lens FG, fig. 41; be placed in the rays at the same distance from the focus that AB is, it will so refract the rays, that they shall go out of it parallel to one another.

Illustration. It is evident that all the rays, except the middle one, cross each other in the focus *f*, of course the ray DA, which is uppermost in going in, is the lowest in going out, as G *c.*

23. If a candle be placed at the focus *f* the diverging rays between FG will, upon going out of the lens, become parallel as *d*, *c*.

237. If the candle be placed nearer the glass than the focus, the rays will *diverge* after going through the lens.

238. If the candle be placed farther from the glass than the focus is, the rays will *converge*, after passing through the glass, and meet in a point, which will be more or less distant from the glass, as the candle is nearer to, or farther from its focus.

239. Where the rays meet they will form an inverted image of the flame of the candle.

Experiment 1. The inverted image of the candle may, by means of a common burning glass, be taken on a sheet of paper, which is to be placed at the meeting of the rays.

2. If any part of the lens be covered, the image will be perfect, but less bright.

3. If an object ABC, fig. 42, be placed beyond the focus F of the convex glass *d e f*, some of the rays which flow from every point of the object, on the side next the glass will fall upon it, and after passing through it they will be converged into as many points on the opposite side of the glass, where the image of the whole will be formed, which will be inverted. Thus the rays flowing from A, as A *d*, A *e*, A *f*, will converge in the space *d a f*, and by meeting in *a* will there form the image of the point A: and so of those rays flowing from B and C, and of course of all the intermediate parts.

4. If the object ABC be brought nearer the glass, the picture *a b c* will be removed to a greater distance from it.

240. The picture will be as much larger or less than the object, as its distance from the glass is greater or less than the distance of the object from it.

Observation 1. Hold a candle on one side of a glass globe, or a globular glass full of water, and let the light that passes through it fall on a sheet of paper, it will be seen that the rays do not all meet in one point, but that they form two curves, called *caustics* by *refraction*.

2. These curves are, in some measure, formed by all lenses, but when the lenses are thin, and the sphericity not very great, they are so trifling, that the eye does not perceive them. Hence lenses should always be small segments of large spheres.

241. When parallel rays pass through a double concave lens, they will diverge, after passing through the glass, as if they had come from a point in the centre of the concavity of the glass. This point is called the *imaginary focus*.

Example. If the rays *a b c*, &c. fig. 43, pass through A B, and C be the centre of concavity, then the ray *a*, after passing through the glass, will go on in the direction *k l*, as if it had come from C and no glass in the way; the ray *b* will go on in the direction *m n*, and so on.

242. When parallel rays pass through a plano-concave lens, they diverge, after passing through it, as if they had come from a point at the distance of a whole diameter of the glassy concavity.

OF REFLECTION.

243. When rays of light strike against a surface, and are sent back from it, they are said to be *reflected.*

244. The ray that comes from any luminous body, and falls upon a reflecting surface, is called the *incident ray.*

Example. If L. G, fig. 38, be a reflecting surface, as a looking glass, then B C is the incident ray, and C E is the *reflected* ray.

245. The *angle of incidence* is that which is contained between the incident ray and a perpendicular to the reflecting surface, in the point of reflection.

246. The *angle of reflection* is that contained between the perpendicular and the reflected ray.

247. The *angle of refraction* is that contained between the refracted ray and the perpendicular.

Illustration. In fig. 38, B C being the incident ray, B C F is the angle of incidence, F C E is the angle of reflection, and I C K is the angle of refraction.

248. The rays of light that fall on any body, are never all reflected. Mercury, which is the best reflector, reflects only about three

fourths of the rays that fall on it, the other being absorbed.

Observation 1. The greater the angle of incidence, or the more obliquely the rays fall on any surface, the more are reflected.

2. When a room is suddenly closed in the day time, the light that was in it, moving at the rate of 200,000 miles in a second, suffers infinite reflections in an instant from the sides of the room; and since at least one fourth of the light is absorbed every time, the room becomes instantly dark.

249. Bodies after having been exposed to the sun's rays for some time, emit a small portion of light in the dark.

Observation 1. This is called the *phosphorescent* property of bodies, and is much more remarkable in some bodies than in others.

2. As the quantity of light thus emitted continually decreases, there would be more given out in the fore part of the night than in the latter part; which explains the reason why the darkest time of night is just before day break.

250. A *mirror or speculum* is an opaque body, whose surface is finely polished, so that it will reflect the rays of light which fall upon it, and thus represent the images of objects.

251. Mirrors are made of metal; or glass, polished on one side and silvered on the other.

252. There are three kinds of mirrors, viz. the *plane*, the *convex*, and the *concave*.

253. Common looking-glasses are called

plane-mirrors; but the concave and convex are denominated mirrors.

254. When a ray of light is reflected from any surface, the angle of reflection is equal to the angle of incidence.

Example. Thus the angle BCF, fig. 38, is equal to FC E. The same is true of convex and concave mirrors.*

255. When parallel rays fall upon a concave mirror, they will be reflected, and meet in a point, at half the distance of the surface of the mirror from the centre of its concavity. This point is called the *principal focus* of the *reflector.*

Example. If the parallel rays, fig. 44, *d a*, C *m b*, and *e c* fall upon the concave mirror AB, then *d a* will be reflected along *a m*, C *b* will be reflected along *b m*, and *e c* along *c m*; of course they all meet in *m*, and *m b* is found to be equal to *m* C, or half C *b*.

256. The rays of light that proceed from any celestial object may be esteemed parallel at the earth, therefore the image of that object will be found half way between the mirror and its centre of concavity.

257. In concave reflectors, the nearer the

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* Let the lines C *a* and C *c*, fig. 44, be drawn, which are perpendicular to the concave surface *a c*, and it will be found that the angle of incidencc *d a* C is equal to the angle of reflection C *a m*, and *e c* C is equal to C *c m*, *m* being *the focus of the reflector*.

focus of *incident* rays, the more remote the focus of *reflected* rays, and *vice versa*.

258. If a luminous body be placed in the principal focus of the reflector, the rays will proceed *parallel* after reflection; if it be placed between the focus and reflector, the rays will *diverge* after reflection.

Observation. If the rays of light, by passing through a lens, or by reflection from a mirror, arrive at a certain point, rays proceeding from that point, and falling on the lens or mirror, will trace the same lines back again.

259. The rays which proceed from any remote terrestrial object will be converged at a little greater distance than half way between the mirror and the centre of concavity, and the image will be inverted with respect to the object. See fig. 45.

260. When the object is more remote than the centre of concavity, the image is less than the object, and is between the object and the mirror.

261. When the object is nearer than the centre of concavity, the image will be more remote and larger than the object.

262. If the object be in the centre of the mirror's concavity, the image and object will be equal, and coincide.

Experiment. If a person stand before a large concave mirror beyond its centre of concavity, he will see an inverted image of himself in the air. And if he hold out his hand towards the mirror, the hand of the image will come out and coincide with it, as if the two were shaking hands. If he reach his hand farther, the hand of the image will pass by it, and if he move his hand to one side, the hand of the image will move to the other. A by-stander will see nothing of the image, because none of the reflected rays can enter his eyes.

Observation. There are many deceptions on the same principle; as the magic flower pot, &c.

263. The rays of light reflected from a concave mirror, do not all meet in one point, but the various foci form two curves, called cat-acaustics, or *caustics* by *reflection.*

Observation. 1. These curves are very observable on the surface of milk in a china bowl when near a candle.

2. The greater the sphericity of the reflector the more observable are these curves. Hence mirrors should be small portions of large spheres. This is also applicable to *convex* reflectors.

264. The images reflected from a convex mirror, appear always smaller than the object, and always as if they were behind the mirror. They never appear exactly of the true shape.

265. Parallel rays falling on a convex mirror, are reflected divergingly; as if they proceeded from a point behind the mirror, at a distance equal to half the radius of convexity. This point is called the *virtual focus* of those rays, or the *principal* focus of the reflector.

266. Diverging incident rays, that is, such as come from near objects, have their virtual

focus nearer the reflector than half the radius of convexity.

267. The reflection of light is supposed to take place not exactly at the surface, because finely polished bodies reflect light regularly, though their surfaces, when examined by means of a magnifier, are very irregular.

Experiments with plane mirrors. 1. Place a candle between two parallel plane mirrors, then, by looking in either, there will appear to be a long row of candles, getting less and less bright, as they recede from the glass. The distance and dimness are owing to the numerous reflections of the rays of light by the mirrors. This experiment, which may be greatly varied, is called the *endless gallery*.

2. Place any body between two plane mirrors united at two edges, their surfaces forming a small angle, and there will appear to be a number of objects, forming a circle.

Observation. The number of degrees in the angle formed by the surfaces, divided into 360, will give the apparent number of objects.

OF THE DIFFERENT REFRANGIBILITY OF THE RAYS OF LIGHT.

268. Light is not a simple homogeneous body, but compounded of seven different species, each of which, in passing obliquely from one medium to another, suffers a different degree of refrangibility.

Observation 1. Whenever a ray of light is refracte is dispersed, or separated into its *primitive colours*, in consequence of some of the rays being more easily refracted or bent, than others. This dispersion was, for a long time, considered to form an insurmountable obstacle to the use of lenses, in constructing optical instruments: but the defect has been greatly remedied, by combining glasses of different dispersive powers, so as to form a lens that will not separate the light into its primitive colours. Lenses of this construction are called *achromatic* or *colourless* lenses.

2. The dispersion, as well as the refraction of rays of light, is increased by an increase of the angle of incidence.

269. To examine the different colours of a ray of light, a small hole must be made in the shutter of a dark room, and the ray must fall upon a prism in an oblique direction.

Illustration. Let AB, fig. 46, represent part of the shutter of the window of a room, in which no light enters, excepting through the hole C. If the light of the sun be received upon a screen at any distance from the hole, as at *E*, a circular luminous spot will be formed upon the screen, which is larger in diameter than the hole at C. Place a glass prism DOE before the hole, so that the light may pass through in the direction perpendicular to the axis of the prism; and instead of going straight from E to F, the light which comes through the hole will, by passing through the prism, be bent and dispersed, in such a manner as to form a coloured spectrum or image GH upon a screen, which may be situated at any distance from the prism, but below the straight direction CF. The spectrum GH, is about five times as long as its breadth, and is terminated by semi-circular ends. The highest part G is of a beautiful *red* colour, which by insensible shades passes into an *orrange*, then a *yellow*, a *geen*, a *blue*, an *indigo*, and a *violet*, which is the colour next to H, viz. at the lowest part of the spectrum.

270. If the whole spectrum be divided into 360 parts, the *red* will occupy 45 of them, the *orange* 27, the *yellow* 48, the *green* and the *blue* 60 each, the *indigo* 40, and the *violet* 80.

Observation. The greatest power of illumination is in the brighest *yellow* or palest *green.*

271. By mixing the seven primitive colours in these proportions, a dusky white is obtained.

Experiment. Paint on a circular board the seven colours in their proper proportions, and then whirl the board with great velocity, it will appear of a dusky white. If the colours were more perfect and accurately defined, the white would be more perfect also.

Experiment 2. Let the rays of the spectrum fall upon a concave reflector and be converged to a focus: they will form a white or colourless image of the sun.

272. The seven colours are reducible to three, viz. the red, the blue, and the yellow.

Observation. Any two prismatic colours will form the intermediate one; thus red and yellow form orange, yellow and blue form green, &c.

273. The most remarkable instance of the separation of the primary colours of light, is that of the *rainbow.*

274. The rainbow is formed by the reflec-

tion and refraction of the rays of the sun's light from the drops of falling rain.

275. The colours of the rainbow are frequently visible among the waves of the sea, the tops of which are blown by the wind into small drops: they are sometimes seen on the ground, when the sun shines on a thick dew.

276. Cascades and fountains frequently exhibit the appearance of rainbows; and water blown violently from the mouth of an observer, whose back is turned to the sun, will produce the same phenomenon.

277. The sun, the spectator, and the centre of the bow, are always in a straight line. Hence the nearer the sun is to the horizon, the larger the arc; and when the sun is *in* the horizon, the arc is a semicircle.

278. There are frequently two bows seen; one without the other. The colours of the inner bow are much brighter than those of the outer one.

Observation 1. Each bow exhibits all the prismatic colours, arranged in the same order that they are in the prismatic spectrum, but in the inner bow, the red is above and the violet below, whilst in the outer bow, the violet is above and the red below. In the outer bow the light undergoes two refractions and two reflections from the drops of water, but in the inner bow there is but one reflection.

2. When the elevation of the sun exceeds 42°, the inner or lower bow cannot appear: and when the elevation exceeds 54°, the outer one cannot appear.

279. A rainbow is also produced in the same way, by the light of the moon; but a lunar *rainbow* is much less vivid than a solar one.

280. *Halos* or *coronas*, are luminous appearances, frequently observed around the sun, moon, or even a bright star or planet. They are circular zones of pale light, mostly white, but sometimes coloured like the rainbow.

Observation. They appear to be formed in such aggregations of vapours as are not heavy enough to fall in drops.

281. The colour produced by any single ray is called a *primary* colour; that produced by a combination of two or more, is called a *secondary* colour.

Observation. Whatever is viewed in any particular coloured ray, appears of that colour. Blood, milk, and grass, viewed in the red ray, will all appear red; viewed in the green ray, green, &c.

282. The colours of bodies are supposed to arise from their absorbing some particular rays and reflecting others.

Illustration. A *red* body is supposed to absorb all but the red rays and reflect them; a *green* body, to absorb all but the green rays, and reflect them, &c. Bodies that have no prismatic colour, are supposed to reflect certain proportions of different rays. *White* bodies reflect equal portions of all the rays, while black bodies absorb all the rays.

OF THE EYE AND VISION.

283. The eye is of a globular form, and is composed of three *coats*, covering one another, and inclosing different substances, called *humours*.

284. The three coats are the *sclerotica*, the *choroides*, and the *retina*.

285. The three humours are the *aqueous*, the *crystalline*, and the *vitreous*.

Illustration 1. ABG, fig. 47. is a section of the globe of the eye, the three circles represent the three coats: the outer one is the *sclerotica*, but the part AEFB, which is more convex than the rest, is called the *cornea*. The middle circle, is the choroides; the fore part of which is called the *iris*, and the inner circle represents the *retina*, which serves to receive the images of objects produced by the refraction of the different humours of the eye. The aqueous humour fills up all the space A,E,F,B, x; y z is the crystalline humour in the form of a double convex lens; and the vitreous humour occupies all the interior part of the eye m n behind the crystalline. From the hinder part of the eye proceeds the optic nerve d, which conveys to the brain the sensations produced on the retina.

Illustration 2. The *iris* is the coloured part of the eye, and it is formed of muscular fibres, disposed in two directions, some are like radii, tending to the centre, and others are circular. The iris is perforated near the centre, and that perforation is called the *pupil*. This pupil is not always of the same size, for by contracting the radial fibres of the iris, and relaxing the circular ones, the *pupil becomes larger*; and by relaxing the radial fibres, and contracting the circular ones, the pupil becomes smaller.

3. By this admirable construction of the pupil, persons are enabled to accommodate their eyes to the brightness of the object they are viewing. When an object is too bright for the eye, the pupil is contracted so as to prevent so much light from falling upon the retina; when it is too dim the pupil is enlarged so as to admit more rays. Were the pupil to be no larger in the brightest moon light, than it is in the day, we should not be able to distinguish objects. On the contrary, were the pupil to continue in the day of the same size it is in the moon-light, we could not endure to open our eyes.

4. When a person goes out of a light room in the evening, he at first can scarcely see any thing, but as the pupil gradually enlarges so as to admit more light, bodies become more visible. If a person go out of the dark into a bright light, his eyes are at first dazzled by the pupil's being expanded and thereby admitting too many rays, but the pupil soon accommodates itself to the light. The change in the size of the pupil may be observed by another person. The pain produced by going from the dark into a bright light, is supposed to be owing to the effort made to contract the pupil.

286. Objects are seen by means of their images being painted on the retina of the eye.

Illustration. The object A,B,C, sends out rays that fall on the *cornea* of the eye between E and F, and by passing on through the pupil and humours, they will be converged to as many points on the *retina*, and will there form a distinct inverted picture *c b a*, of the object. Thus the pencil of rays *q r s*, that flow from A, will be converged to the point *a* on the retina; those from B will be converged to the point *b;* those from C to the point *c;* and so of all the intermediate points; by which means the whole picture *a b c* is formed, and the object is made visible.

Experiment. If the thicker coats, from the back part of a fresh eye, be removed, and the eye thus prepared be turned towards objects well illuminated, their pictures may be clearly perceived through the remaining thin coat, painted on the back part of the eye in an inverted position.

287. Though the images of objects are painted on the retina in an inverted state, yet they are seen erect.

Illustration 1. Various opinions have been advanced in explanation of this phenomenon, the most plausible of which is that the mind contemplates the *object*, and not its image, and that by experience we are accustomed to consider the *lower* part of the picture, as indicating the *upper* part of the object, and *vice versa.*

2. We also refer the situation of objects to the surrounding bodies. If a person turns his head upside down, although the images are contrary to their usual position upon the retina, he does not imagine the objects to be inverted.

288. Dimness of sight generally attends old people, which may arise, either, 1st, by the eyes growing too flat, and not uniting the rays at the retina: or, 2d, by the humours losing their transparency in some degree, which makes every object appear faint and indistinct.

289. Spectacles are intended to assist the sight of those whose eyes are either too round or too flat.

290. *Concave* glasses are necessary to those whose eyes are too round.

Illustration. When the eye is too round, the rays proceeding from objects are converged to a focus before they get to the retina; to remedy this, a concave glass is used, because the property of this is to *disperse* the rays, which prevents them from coming to a focus so soon as they otherwise would.

291. Convex glasses are necessary to those whose eyes are too *flat.*

Illustration. When the eye is too flat, the rays proceeding from objects do not converge to a focus so soon as they reach the retina; a convex glass has the property of converging the rays, and of course of bringing them to a focus sooner than they otherwise would.

292. Eyes that have their humours of a due convexity cannot see an object distinctly at a less distance than about seven inches.

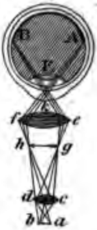
293. There are numberless objects too small to be seen at a distance.

294. The rays which enter the eye from distant objects, will evidently arrive at a focus sooner than those which proceed from near objects. Hence if the former fall upon the retina, it would require a different adjustment of the eye, in order that the latter may. This alteration does actually and necessarily take place, and is called the *accommodation* of *the eye* for *distinct vision.*

Optics.

VI.

48



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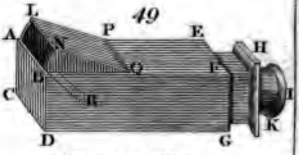
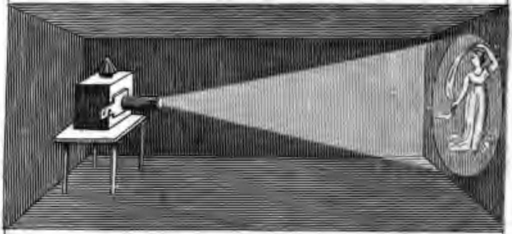


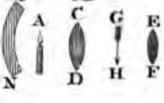
Camera Obscura

50



Magic Lanthorn

51



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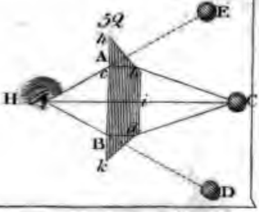


B. Tanner Sc.

Observation. This accommodation is effected, either a change in the length of the eye, or by a change in shape or situation of the crystalline lens.

295. We judge of the distance and size objects, first, from their apparent magnitud 2dly, from their brightness and the distinctne of their minute parts; 3dly, from the directio of the two eyes; and 4thly, from their situati in relation to other objects; and our judgment more or less liable to be wrong, according one or more of these circumstances are wantin

Illustration 1. A person with one eye, cannot judge of distances, as will be found by attempting to a candle with one eye closed.

2. Take a bent stick six or seven feet long, and one eye closed, attempt to put one end in a ring 4 inches in diameter held edgewise, it will seldom be d at the first trial.

3. When the sun or moon is in the horizon, the thi ness of the atmosphere renders it less bright than i when higher up; also there are a great many things tween it and us, and it is beyond the farthest we can on both these accounts we imagine it to be a great farther off than when it is higher, and consequently th it is larger. This explains the phenomenon of *the h zontal moon.*

OF OPTICAL INSTRUMENTS.

296. Microscopes are instruments for vie *ing small objects.*

297. They apparently magnify objects, because they enable us to see them nearer without affecting the distinctness of vision.

Experiment. Take a piece of brown paper and make a pin hole in it, then bring the eye close to the hole, and the paper within two or three inches of a small print, which will be apparently much magnified, though without the paper the letters would at that distance be wholly illegible.

298. There are three kinds of microscopes, the *single*, the *compound*, and the *solar*.

299. The single microscope, is only a small double convex lens, having the object placed in the focus, and the eye at the same distance on the other side.

300. The magnifying power of the single microscope is found by dividing seven inches, the least distance at which an object can be seen distinctly by the naked eye, by the focal distance of the lens.

Illustration. By the experiment just mentioned, the brown paper was brought twice or three times nearer the book than the distance of distinct vision, and the length of the letters was magnified two or three times. Through a lens, whose focal distance is only one inch, an object would appear to be seven times longer than it is, and the surface would be magnified 49 times, that is, the square of 7.

Experiment. If the focal distance of the lens be only one-fourth of an inch, then the diameter of an object will be magnified 28 times (because 7 divided by one-fourth is the same as multiplying 7 by 4) and the surface will be magnified 784 times.

301. The compound microscope consists of an object-glass and an eye-glass.

Illustration. The object to be viewed is *a b*, fig. 48, *c d* is the object glass, and *e f*, the eye-glass. The object is placed a little beyond the focus of *d c*, the rays will converge and the image be formed at *g h*. The image, therefore, and not the object, is viewed by the eye DE, through the lens *e f*, which is so placed that the image *g h* may be in its focus, and the eye about the same distance on the other side; the rays of each pencil will be parallel, after going out of the eye-glass as at *e* and *f*, till they come to the eye at *k*, where they begin to converge by the refractive humours of the eye, and having crossed each other and passed through the crystalline and vitreous humours, they will form the inverted image AB on the retina.

302. The magnifying power of the compound microscope is in proportion as the image is larger than the object, and also according as we are liable to view it at a less distance.

Example. If the image *g h* is 4 times larger than the object *a b*, and by the help of the eye glass we can view it 7 times nearer than we could by the naked eye, on both these accounts the diameter of the object will be magnified 4 times 7, or 28 times; and the surface 784 times.

303. There are generally two eye-glasses, by which means the object is less magnified, but more of it is seen.

304. The solar microscope depends on the sunshine, and is used in a darkened room.

305. It is composed of a tube, a looking-glass, a convex lens, and a single microscope.

306. The sun's rays are reflected by the *looking-glass* through the tube upon the object, the image of which is thrown upon a white screen, sheet, &c. placed at a distance to receive it.

307. The magnifying power of the instrument is in proportion as the distance of the image from the object-glass is greater than the object itself is from it.

Example. If the distance of the object from the object-glass be one-fourth of an inch, and the distance of the picture be 10 feet, or 120 inches, then the object is magnified in length 480 times.

308. Telescopes are used for viewing objects at a great distance; of these, there are two kinds, the *refracting* and the *reflecting*.

309. The common refracting telescope consists of an object-glass which is nearest the object, and an eye-glass next the eye.

310. This telescope inverts the image with respect to the object, which makes it unfit for viewing terrestrial objects.

311. The magnifying power of this telescope is as the focal distance of the object-glass is to the focal distance of the eye-glass.

Therefore, if the former be divided by the latter, the quotient will express its magnifying power.

Example. An object-glass of 10 feet, or 120 inches, focal distance will admit of an eye-glass whose focal distance is 2 and a half inches, and 120 divided by 2 and a half will give 48, the number of times that such a telescope will magnify the diameter of an object.

312. A telescope to show objects in their natural posture has three eye-glasses. The two additional lenses is to give the erect position of objects. See fig. 41.

313. The three eye-glasses have all their focal distances equal, and the magnifying power is found, as before, by dividing the focal distance of the object-glass by the focal distance of one of the eye-glasses.

Observation 1. If a telescope be *inverted*, the objects will appear smaller and more distant.

2. The largest telescope ever made was constructed by Dr. Herschel. It is a reflecting telescope, in using which the observer has his back to the object. The polished surface of the reflector is 40 inches in diameter. The reflector weighs 2000 lbs. The length of the tube is 40 feet. It magnifies about 6000 times. The image of the object is reflected from the mirror, and intercepted by a lens at a proper distance, through which the observer receives the image upon his eye.

314. The *camera obscura* is made by fixing a *convex glass* in a hole of a window shutter,

and if no light enters the room but through the glass, the pictures of all objects on the outside may be seen in an inverted position on a white paper placed in the focus of the lens.

315. If the convex lens be placed in a tube in the inside of a box, within which is a looking glass sloping backwards, we get a portable camera obscura.

Illustration. Fig. 49 represents a box consisting of two parts. The outer ACBDEFG has a shutter or cover LN, which moves round a hinge PQ, and when open, as in the figure, it carries two lateral boards, which serve to exclude the external light as much as possible from the rough glass O, upon which the observer is to look. The fore side of the box is wanting, and in that aperture another narrower box EHIKG slides. This box wants the inner side, and has a convex glass lens fixed at I. If this machine be turned with the lens I towards any objects that are well illuminated, an inverted picture of them will be formed within the box on the side ABCD, and that picture may be rendered distinct by moving the sliding box EHGK in or out, in order to adjust the focus according to the distance of the objects. At the back part of the box a flat piece of looking-glass is situated at an inclination of half a right angle, as is shown by the dotted lines B R; in consequence of which the rays of light fall upon the looking-glass, and are reflected upwards to the rough glass O. The picture then is formed upon the rough glass, and will appear erect to a spectator, situated behind the box, and looking down upon the glass O, from which a drawing may be made.

316. The *magic lantern* is an instrument *used to magnify* paintings on glass, and throw-

ing their images upon a white screen in a darkened chamber.

Illustration. Fig. 50 represents the machine, with the effect it produces. Fig. 51 shows the internal parts of the machine placed at their proportionate distances. The lantern contains a candle A, a reflector MN, which is so situated as to have the light A in its focus. On the fore part of the lantern there is a thick double convex lens C D, or a plano convex (usually called a bull's eye) of short focus. The lantern is closed on every side, so that no light can come out of it, but what passes through the lens CD. In the direction of this lens there is a tube *x*, fig. 50, fixed to the lantern, which has a lateral apperture from side to side; through this the glass slider *a a* with the painted small images is moved in an inverted position. GH, fig. 51, represents one of these images. The fore part of the tube *x* contains another sliding tube, which carries the double convex lens EF. The effect of those parts is as follows: The thick lens CD throws a great deal of light from the candle A upon the image GH. And to increase that light still more, the reflector MN is often, but not always, placed in such lanterns; for as the flame is in the focus of the reflector, the light proceeds in parallel lines from the reflector to the lens CD. The image GH being thus well illuminated, sends forth rays from every point, which, by passing through the lens EF, are converged to a focus upon the wall and form the large images, as is shown in fig. 50. In some magic lanterns, instead of the single lens EF, two lenses are used of less curvature, and set at a little distance from each other; which act rather better than a single lens.

317. The multiplying glass is made by grinding down the side of a convex glass into several flat surfaces.

Illustration. Fig. 52 is the representation of a multiplying glass with three flat sides *h i k*. The object C seen by the eye at H will appear multiplied into as many different objects as the glass contains plane surfaces. For since rays flow from the object C to all parts of the glass, and each plane surface will refract these rays to the eye, the same object will appear to the eye in the direction of the rays, which enter it through each surface. Thus the rays falling in the direction C *i* H will show the object in its true place at C, because there they suffer no refraction; but the rays falling upon the surfaces *h b* and *d k*, will be refracted to *e* and B; and therefore to an eye at H, the object C will appear in the directions H *e* E and HBD, as well as in that of H *i* C. The same thing will happen, if instead of three there be any number of flat surfaces.

ASTRONOMY.

318. Astronomy is the science which explains the forms, numbers, distances, motions, and appearances, of the celestial bodies.

319. The celestial bodies are the sun, the planets with their moons, the comets, and the fixed stars.

320. The earth, which appears to us like a vast plane, is, in reality, a round, or convex surface.

Illustration 1. That the earth is spherical is proved, 1. From its casting a round shadow upon the moon during an eclipse. 2. From its having been sailed round *by several persons.* 3. From our seeing farther the higher we stand. 4. From our seeing the masts of ships on the sea while the hull is hidden by the convexity of the water.

2. As the earth is spherical and all bodies tend towards its centre, persons on opposite sides of it stand with their feet towards each other; these are called *antipodes.*

3. Hence in regard to space, there is no real *up* and *down*, for the direction which is called *up* on one side is exactly contrary to that which is called *up* on the other. But in relation to the earth, that is called up which is further from the centre, and that is called down which is nearer to the centre.

4. The earth is not a perfect sphere, but has the equatorial diameter, about 25 miles longer than the polar diameter.

321. The *sensible* horizon is that apparent circle which, on an extensive plane, seems to circumscribe our sphere of vision.

322. The *rational* horizon divides the heavens into two equal parts or hemispheres; the visible which is above, and the invisible which is below it.

323. The Sun, the Moon, the planets, and most of the stars, appear to go continually round the earth from east to west, and to perform each revolution in about 24 hours.

Observation. This apparent motion of the heavenly bodies, is occasioned by the revolution of the earth upon its axis from west to east.

324. The *axis* of the earth is an imaginary

line about which it revolves, passing throug its centre from north to south.

325. The *poles* are the extremities of th axis; that on the north is called the *arctic* pol that on the south the *antarctic.*

326. On turning our back towards the *nort* we have the *south* exactly before us, the *ea* on the left, the *west* on the right, the *zenit* over our heads, the *nadir* under our feet.

327. The equator, or equinoctial, is tha great circle equally distant from the pole which divides the globe into two equal part called northern and southern hemispheres.

328. The same circles, planes, &c. are sup posed to exist in the heavens, as well as upo the earth: so that the south and north poles c the heavens are said to be situated precisel over those of the earth.

329. The whole sphere appears to perforı its revolution regularly in the space of 2 hours 56 minutes and 4 seconds.

330. The *meridian* is a circle passin through the north and south poles, and th zenith and nadir of a place. It divides th earth into two hemispheres, called *eastern* an *western.*

331. The meridian divides the time of th course of the heavenly bodies above and b low the horizon into two equal parts; henc when the sun is at the meridian *above* the h

rizon, it is called *midday;* and when at the meridian *below* the horizon, it is called *midnight.*

332. Circles that pass through the zenith and nadir of a place are called *vertical circles.* They are at right angles to the horizon.

333. The vertical circle which is at right angles to the meridian is called the *prime vertical.* When any heavenly body is in the prime vertical, it is exactly east or west of the spectator.

334. The points where the meridian cuts the horizon, are called the *north* and *south* points; the points where the prime vertical cuts the horizon, are called the *east* and *west* points. These four are called the cardinal points.

335. The arc of the horizon, between the north and south points, and a vertical circle passing through any heavenly body, is called the *azimuth* of that body; and the arc of the horizon between the east and west points and said vertical circle, is called the *amplitude.*

336. The sun rises and sets every day at different points of the horizon, and crosses the meridian every day at a different point; but never goes farther from the equator than about 23° 28′, either towards the north or towards the south of it.

337. The *ecliptic* is the Sun's apparent an-

nual path; the angle which it forms with the equator is called the *obliquity* of the *ecliptic*, and the points where it intersects the equator are called the equinoctial points.

Obs. The obliquity of the ecliptic is about 23° 28′

338. The equinoctial point in which the sun is in the spring, is called the *vernal* equinox, the other is called the *autumnal* equinox.

339. The ecliptic is supposed to be divided into 12 equal parts called signs, each of which contains 30 degrees.

340. The names and characters of the signs are, 1. Aries ♈, 2. Taurus ♉, 3. Gemini ♊, 4. Cancer ♋, 5. Leo ♌, 6. Virgo ♍, 7. Libra ♎, 8. Scorpio ♏, 9. Sagittarius ♐, 10. Capricornus ♑, 11. Aquarius ♒, 12. Pisces ♓.

341. The signs go round the ecliptic from west to east, in the order in which they are mentioned. Aries beginning at the vernal equinox.

342. The first six are on the north side of the equator, and are called *northern* signs; the others are on the south side and are called *southern* signs.

343. The zodiac is a broad portion of the heavens, following the direction of the ecliptic and extending about 8 degrees on each side of it, so as to include the latitude of all the planets except three of those recently discovered.

Observation. The stars in the zodiac are divided into 12 constellations called the *signs* of the *zodiac;* they give names to the *signs* of the *ecliptic.*

344. As the sun appears every day in a different point of the ecliptic, it thence seems to revolve in a circle parallel to the equator, but receding from it first about 23° 28′ towards the north, then approaching the equator, and again receding from it about 23° 28′ towards the south, and so on.

345. The *tropics* are the circles parallel to the equator which the sun seems to describe, when at its greatest distance from the equator, that towards the north being called the tropic of Cancer, and that towards the south the tropic of Capricorn.

346. The *polar circles* are circles parallel to the equator 23° 28′ from the poles.

347. Any circle which passes through the poles of the ecliptic is called a *circle of latitude.* A circle of latitude is at right angles to the ecliptic.

348. The arc of the ecliptic, in the order of the signs, between the vernal equinox and a circle of latitude passing through any heavenly body, is called the *longitude* of that body.

449. The *latitude* of a heavenly body is its distance north or south of the ecliptic: it is measured on a circle of latitude.

350. Any circle that passes through the

poles of the equator, is called a circle of *declination.* A circle of declination is at right angles to the equator.

351. The arc of the equator, in the order of the signs between the vernal equinox and a circle of declination passing through any heavenly body, is called the *right ascension* of that body.

352. The *declination* of a heavenly body, is its distance north or south of the equator. It is measured on a circle of a declination.

Observation 1. When two heavenly bodies have the same longitude, they are said to be in *conjunction* with each other. When their longitudes differ 180 degrees they are said to be in *opposition.*

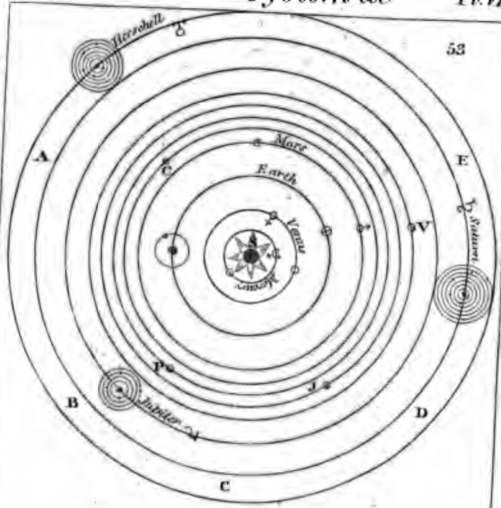
2. The longitude and latitude of a heavenly body as seen from the earth, are called its *geocentric* longitude and latitude, but as seen from the sun, its *heliocentric.*

353. When any heavenly body comes into view in the east, it is said to rise; and when it disappears in the west, it is said to set.

Observation 1. To a person situated at the equator, all the heavenly bodies rise and set every 24 hours, and are just as long above, as below the horizon. But to a person *north* of the equator, all the stars whose distance from the north pole is less than the latitude he is in, will perpetually revolve about the pole, and never go below his horizon; while those within the same distance of the south pole, will never come above his horizon. These are called *circumpolar* stars. The star nearest the north pole is called the *north star.* The north star is not visible south of the *equator.*

Solar System &c Pl. VII.

53



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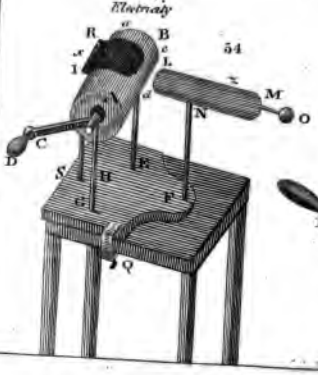

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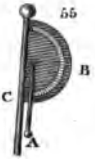

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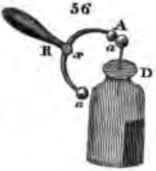


2. To a person in *south* latitude, the stars about the *south* pole never set, and those about the *north* pole never rise.

3. The altitude of the pole is always equal to the latitude of the place.

OF THE SOLAR SYSTEM.

354. If a person direct his attention to the heavens for several successive nights, he will find first, that most of the stars remain always in the same position with respect to each other; these are called *fixed stars.*

355. He will find that a few have a motion amongst the fixed stars, sometimes moving from *west* to *east*, and sometimes from *east* to *west.* These are called *planets.*

356. He will observe that the moon has a motion amongst the fixed stars, always from west to east, and that it is continually changing in the size of its illuminated surface, being more illuminated, the farther it is from the sun.

357. He will observe that the sun has an apparent motion amongst the fixed stars from west to east.

358. If he use a telescope, he will also observe that the planets, Venus and Mercury, exhibit phases like the moon, but never appear

quite full; and that the other planets at times deviate sensibly from a circle. To explain these phenomena, various hypotheses have been offered, of which the one that is now universally received, is called the *Copernican or Solar System.* It was taught by Pythagoras 500 years before Christ, revived by Copernicus in the 16th century, and afterwards demonstrated mathematically by the incomparable Newton.

359. According to the Copernican system, the sun is the centre of the system, about which the *primary* planets revolve from west to east at different distances and in different times; and the *secondary* planets or moons revolve around their primaries, and are carried with them around the sun.

360. The solar system consists of eleven primary planets, eighteen secondary planets or moons, and a number of comets.

361. The names of the primary planets are Mercury, Venus, the Earth, Mars, Vesta, Juno, Ceres, Pallas, Jupiter, Saturn, and Herschel.

362. The earth has one moon, Jupiter four, Saturn seven, and Herschel six. The other seven planets do not appear to have any moons.

Illustration. The sun S, plate vii. fig. 53, is the centre of the system; nearest to the sun revolves Mercury ☿, then Venus ♀, the Earth ⊕, Mars ♂, Vesta Juno, Ceres, *Pallas, Jupiter* ♃, Saturn ♄, and Herschel ♅.

363. All the planets move round the sun from west to east; and in the same direction do the moons move round their primaries.

Observation. The satellites of Herschel have been thought by some to move from east to west.

364. The paths in which the planets move are called their orbits.

365. The orbits of the planets, though circular in the figure, are in nature elliptical, the sun being in one focus.

366. The planets perform their revolutions round the sun in different periods of time; the time of performing their revolution is called their year.

367. The planets turn on their axes, and the time employed for this purpose is called their day.—*See following page.**

368. The planets and their moons are opaque bodies, and shine only by reflecting the light which they receive from the sun.

Illustration. Mercury and Venus, when viewed by a telescope, seem often to be only partly illuminated, and have the appearance of our moon when she is horned; having the illuminated part always turned to the sun. From the appearance of the boundary of the light and shadow upon their surfaces, it is concluded that they are spherical; a circumstance which is confirmed by their having been found to turn on their axes.

369. Venus and Mercury being nearer the sun than the earth is, are called inferior pla-

* The following table will give the tropical, siderial, and synodic revolutions of the sun and planets, the times occupied in their diurnal revolutions on their axes, their mean diameters and mean distances from the sun in miles, and their relative densities to that of water, which is unity.

	Tropical Revolutions.				Siderial Revolutions.	Synodic Revolutions.	Rotation on their axes.			Mear diameters ir	Mean distances from the sun, in round	Densities to that of water, which is 1.
	Days	h.	m.	s.	Days.	Days.	d.	h.	m.	Miles.	numbers of Ms.	
The Sun						115	25	14	8	883246		1 2-15
Mercury	87	23	14	33	87.969258	584	0	24	5	3224	37,000,000	9 1-6
Venus	224	16	41	27	224.700787		0	23	21	7687	68,000,000	5 11-15
The Earth	365	5	48	48	365.256384		1	0	0	7920	95,000,000	4 1-2
The Moon							29	17	44	2180	95,000,000	5 1-2
Mars	686	22	18	27	686.979646	780		24	39	4189	144,000,000	3 2-7
Vesta					1326.930000	504				238	225,000,000	
Juno					1594.023000	474				1425	254,000,000	
Ceres					1681.370000	467				16	260,000,000	
Pallas					1685.619000	466				8	266,000,000	
Jupiter	4330	14	39	2	4332.585117	399		9	56	8917	490,000,000	1 1-24
Saturn	10746	19	16	15	10758.322161	378		10	16	7904	900,000,000	13-32

nets; and all the others being without the earth's orbit, are called *superior* planets.

Illustration 1. It is certain that Mercury and Venus go round the sun, because they are sometimes seen passing between the earth and sun, and sometimes they go behind the sun.

2. Their orbits are within that of the earth, because they are never seen in *opposition* to the sun; that is, they never appear to rise from the horizon when the sun is setting.

3. The orbits of all the other planets are known to surround that of the earth, for they are sometimes seen in opposition to the sun, and they never appear to be horned, but always nearly or quite full.

370. When a planet is situated so as to be between the sun and the earth, or so that the sun is between the earth and planet, then the planet is said to be in *conjunction* with the sun.

Observation. When an inferior planet comes between the earth and sun, it is said to be in *inferior* conjunction; but when it is beyond the sun, it is said to be in *superior* conjunction.

371. When the earth is between the sun and any planet, then that planet is said to be in *opposition.*

372. The inferior planets have two conjunctions with the sun in each revolution, but the superior planets have only one, because

they can never come between the earth a
sun.

373. When a planet comes directly b
tween the earth and sun, it appears to pa
over the sun's surface, and this is called t
transit of the planet.

374. The planets move faster when th
are nearest the sun, and slower in the rem
test part of their orbits.

Observation. In consequence of this, and the sun bei
further from the earth in summer than in winter, it
about eight days longer on the north side of the equa
than on the south side.

375. The apparent distance of a plan
from the sun is called its *elongation.*

376. When the apparent motion of a plar
is in the order of the signs, that is, from we
to east, it is called direct; when in the contr
ry way, it is called *retrogade.*

Observation. When an inferior planet is in superior c
junction, its motion is direct from west to east, its el
gation continually increasing, till it gets to its gre t
eastern elongation. It will then appear to be *station*
for some time; that is, it will neither appear to get ne
er to, nor farther from, the sun, in consequence of
motion in its orbit being directly towards the earth.
will afterwards have a *retrogade* motion from east
west, through its inferior conjunction, till it gets to
greatest western elongation, when it will be *station*
again for some time, in consequence of its motion in
orbit being directly from the earth. Its motion will th
be direct, from west to east, through its superior conju
tion.

2. To a spectator at Jupiter, or any superior planet, the earth would be an inferior planet, and would have the same apparent motions and phases that Venus and Mercury have to us.

3. The motion of a superior planet is direct when in conjunction, and retrogade when in opposition.

377. The time a heavenly body is in revolving round the sun from any *degree* in its orbit, till it returns to the same degree again, is called a *tropical revolution*.

378. The time a heavenly body is in going from any fixed star, till it returns to it again, is called a *siderial revolution*.

Observation. The equinoctial points have a motion round the equator from east to west, or contrary to the order of the signs, which causes a planet to arrive at the same degree in its orbit, *sooner* than it arrives at the same fixed star. This motion of the equinoctial points is hence called the *precession* of the *equinoxes*, and is about 50″.1 in a year; it must therefore require 25869 years to perform a complete revolution.

379. The time between two consecutive conjunctions or oppositions of a body with the sun, is called a *synodic revolution* of that body.

Observation. The synodic revolution of Venus or Mercury, is the time from one inferior conjunction, or from one superior conjunction to another.

380. The sun is a spherical body of immense magnitude, being about a million of times as large as the earth.

381. The diameter of the sun is about 8
thousand miles.

Observation. The distance from the centre of the s
to its surface, is nearly twice as far as the moon is from
earth; therefore, if the earth were placed at the centr
the sun, the moon, at nearly twice its present distance fr
the earth, could revolve around it within the sun's surfac

382. When viewed through a telesco
several dark spots are seen adhering to
surface. From these spots it is found t
the sun turns on its axis in about 25 days.

383. By Dr. Herschel and others it
thought that the sun is a most magnific
and habitable globe.

Observation 1. It is supposed that the sun is surroun
by a luminous atmosphere, and that it is *this atmosph*
and not the *body of the sun*, that emits light; and owin
different states of this atmosphere, the sun is bright
some times than at others.

2. The sun has a motion about the centre of gravit
the solar system; but being so much larger than all
planets taken together, the centre of gravity is a consid
ble distance within the sun's surface.

3. The sun is also supposed to have a motion, eit
rectilinear in absolute space, or around some distant
unknown centre.

384. Mercury is the planet nearest to
sun, and on that account is very seldom v

ble. It shows phases like the moon, but never appears to us quite full.

385. The diameter of Mercury is near 3200 miles. It revolves around the sun in about 88 days. Mercury's greatest elongation from the sun is about 28 degrees.

386. At the time of the inferior conjunction of Mercury, if its latitude be less than the semi-diameter of the sun, it appears to pass over the sun's surface. This is called *a transit of Mercury.*

Observation. The first transit of Mercury visible at Washington will be on the 7th of November, 1835; it will begin about half past twelve, and continue till sun set; the next on the 8th of May, 1845, beginning about eleven o'clock and continuing 6 3-4 hours; the next the ninth of November, 1848; it will begin before sun rise, and end about a quarter past eleven o'clock.

387. Venus is the brightest, and, to appearance, the largest of all the planets.

388. The diameter of Venus is near 7600 miles; its siderial revolution about 224½ days; and its greatest elongation 48 degrees.

Observation. When the elongation of Venus is about 40 degrees, between its inferior conjunction and greater elongation (which is about 36 days before and after its inferior conjunction) it appears the brightest. In that situation, when the atmosphere is clear, it can be seen by the naked eye at noon-day if above the horizon, even when the sun is shining with its greatest splendour.

389. When at the time of inferior conjunction, Venus's latitude is less than the semi-diameter of the sun, it appears to pass over the sun's surface. This is called a *transit of Venus.*

Observation. A transit of Venus takes place much less frequently than a transit of Mercury. The last transit of Venus was in 1769, and the next will be in 1874, 1882, and 2004. The one in 1882 will be visible at Washington. It will be on the 6th of December, beginning about a quarter past eight, and ending about half past two o'clock.

390. Venus is generally called the morning or evening star, according as it precedes, or follows, the apparent course of the sun.

391. By the transit of Venus the sun's distance from the earth was first accurately ascertained.

392. The earth is not a perfect sphere, but a spheroid, having the diameter at the equator about 25 miles longer than that at the poles.

393. The mean diameter of the earth is about 7920 miles, and its mean distance from the sun is 95 millions of miles.

394. The earth being of a globular form, people stand upon opposite sides of it, and these are called *antipodes* to each other.

395. The earth has a *diurnal* motion about *its axis, and* an annual one about the sun.

396. The diurnal motion of the earth is the cause of day and night.

Illustration. When one half of the earth is turned towards the sun, it receives his rays, and is illuminated, causing day; and when this half is turned from the sun, we are in darkness, and then we have night.

Observation 1. The difference between the earth's greatest and least distances from the sun, is about three millions of miles, the earth being about three millions of miles nearer to the sun in winter than in summer.

2. The reason why it is warmer in summer than in winter, notwithstanding the earth is further from the sun, is, first, that the sun is a greater part of the time above the horizon than in winter; and secondly, being north of the equator, it shines more vertically, and a greater number of rays fall upon the same surface.

397. The tropical revolutions of the earth, is 365 days, 5 hours, 48 minutes, 48 seconds; which period is called the *year* in civil reckoning.

Observation 1. The *common* year consists of 365 days, and every fourth year, called *leap year*, of 366. Every year which divides evenly by 4 is a leap year, except the centuries. A century, the *number* of which divides evenly by 4, is a leap year; the others common years. Thus, 1800, 1900, 2100, 2200, &c. are common years; 2000, 2400, 2800, &c. leap years.

2. At the council of Nice, A D. 325, the vernal equinox fell on the 21st of March, but by computing every year at 365 days, 6 hours, which is 11 min. 12 sec. more than the true year, in 1582 it fell on the 11th. It was therefore ordered by Pope Gregory XIII. that the calendar *should be corrected* by taking 10 days from it, and having

every century which is not divisible by 4, as 1800, 1900, &c. to be common years. Accordingly in 1582, the day following the 4th of October, was called the 15th; by means of which the real equinox was restored. This manner of reckoning is called the *Gregorian*, or *New Style;* the other, the *Julian*, or *Old Style.* As 1700 and 1800 were both leap years in the old style, and common years in the new, the new style is now twelve days further in the year than the old.

3. The new style is used in all civilized countries excepting Russia.

398. Since it is 12 o'clock at a place when the sun is on the meridian, it is 12 o'clock sooner at any given place, than it is in a more western situation. This is called the *difference* of *meridians* in time.

Observation. The difference of longitudes of two places converted into time, at the rate of 15 degrees to one hour, gives the difference of time at the two places, it always being *later* to the east, and *earlier* to the west.

399. The light from the sun being about eight minutes in coming to the earth, the sun always appears to be further east than it really is.

Illustration. The light of the sun that falls upon our eyes at any time, left the sun eight minutes previously. It therefore represents the sun in the situation it was eight minutes before. But in eight minutes the sun moves about 2 degrees westward; consequently it is always about 2 degrees *west* of its apparent place.

400. Twilight is owing to the refraction of the rays of light by our atmosphere, through which they pass, and which, by bending them, occasion some to arrive at a part of the earth, that could not receive any direct rays from the sun.

Observation. The *longest* twilight is on the longest day; the shortest in the latitude of Washington, is about the 6th of March, and the 8th of October: and at these times the *zodaical light*, a pyramid of light in the zodiac, is best observed.

401. The atmosphere possesses the property of reflecting the rays of light in all manner of directions. Were it not for this property, the whole heavens would be entirely dark, except in the particular direction of the sun, planets, or stars; and the planets and stars would be visible during the day.

402. The blue appearance of the heavens, is occasioned by our looking at the dark vacuity beyond our atmosphere, through an illuminated medium.

Illustration. Were there no atmosphere, it would be entirely dark except in the direction of the sun, &c. The more transparent the atmosphere is, the darker is the appearance of the heavens. It is always a darker colour in the zenith, than near the horizon, because there is a less body of atmosphere and vapour, to reflect the light. On the tops of high mountains, the heavens appear nearly black. This is owing to the atmosphere being so rare as to reflect but little light.

403. The axis of the earth, in its journey

round the sun, is inclined to the plane or level of its orbit.

404. This inclination of the earth's axis, in its annual motion round the sun, occasions the diversity of the seasons.

Illustration. The lengthening and shortening of the days and the different seasons are produced by the motion of the earth T, plate ix, in its orbit round the sun S. The axis of the earth, NS, inclines to the plane of the orbit, and is parallel to itself in all parts of its orbit. In June the North pole N inclines to the sun, and it is summer to the northern parts of the earth; in December the North pole declines from the sun, and the northern parts have more darkness than light, and to them the days are short, and it is winter. In March and September the axis of the earth is perpendicular to the centre of the sun, and the poles of the earth NS are in the boundary of light and darkness, and the days and nights are equal all over the earth.—*See Frontispiece.*

405. The moon, next to the sun, is the most remarkable object in the heavens. It is a spherical body, like the earth, round which it revolves, and by the influence of which it is carried round the sun.

406. The average distance of the moon from the earth is 240,000 miles.

407. The moon appears to turn on her axis in the time of her apparent revolution round the earth, viz. in about 29½ days.

Cor. Thence the moon has always the same side towards the earth.

Observation. The moon *really* turns on her axis in the time she performs a siderial revolution round the earth, *viz. in about* 27 1-3 days.

408. The moon's year is of the same length as that of the earth, but the number of her days is very different. To the earth there are 365¼ days in a year: to the moon only about 12½.

409. The moon, at its *conjunction*, is invisible, its first appearance afterwards is called *new* moon.

410. At its *opposition* its whole disk is enlightened, it is then called *full* moon.

Illustration. Plate x, S is the sun, T the earth, ABC, &c. the moon in its orbit. One half of the moon is always enlightened by the sun. At A, the moon is between the earth and sun, and is invisible, as represented at *a:* at B the enlightened part *x*, *x*, is turned to the earth, and she appears horned as at *b:* at C the half of the enlightened side is turned to the earth, and she appears as half moon as at *c:* at D the part *x z* is turned to the earth, and it appears as at *d*, and at E the whole of the enlightened part of the moon is turned to the earth, and we have full moon as at *e*. As she passes through the rest of the orbits, she puts on the same phases as before, but in contrary order.

Observation. In winter the moon fulls on the north side of the equator, which gives the people in high north latitudes the benefits of the full moon, constantly, for several days, during the absence of the sun.

411. The earth is a satellite to the moon, and subject to the same apparent changes as that body undergoes.

412. The earth appears more than 13

times larger than the moon appears to us. At new moon to us the earth appears full to her.

Observation. Within four or five days before and after conjunction, the part of the moon that can receive no direct rays from the sun, appears to be fully illuminated, so that the whole circle of the moon is seen. This is occasioned by the earth having its illuminated surface, at that time, turned towards the moon, reflecting the sun's light to the moon, and the moon again reflecting it to us.

413. The moon is seen by means of the light from the sun, which is reflected to us.

414. Its changes depend upon its situation relatively to the earth and sun.

415. When the moon is in the part of its orbit nearest the earth, it is said to be in *perigee;* when in the remotest part of its orbit, it is said to be in *apogee.*

416. When the earth or any other planet is in the part of its orbit nearest the sun, it is said to be in its *perihelion;* when most distant from the sun, it is said to be in its *aphelion.*

417. Mars is the planet whose orbit is next beyond the earth's. His diameter is about 4000 miles. He revolves around the sun in about 687 days, and on its axis in 24 hours 39 minutes.

418. The disc of Mars never appears horned, like the inferior planets Mercury and Venus, but in particular situations it deviates sensibly from a circle.

Observation. None of the superior planets show phases like Venus and Mercury, but when their distance from the sun is about 90°, they appear *gibbous*, that is, like the moon two or three days before or after it is full.

419. Mars is distinguished from all the other planets by the remarkably red colour of his light. This is supposed to be caused by his having a very dense atmosphere.

420. The apparent size of Mars is subject to great changes. When in opposition, being nearest the earth, he is much brightest, and appears nearly as large as Jupiter. This is about once in 780 days, which is the synodic revolution of Mars.

Observation. All the superior planets are apparently largest and brightest when in opposition to the sun, because they are then nearest to the earth.

421. Vesta is a small planet next to Mars. It was discovered by Dr. Olbers of Bremen in 1807.

422. Juno is next to Vesta. It was discovered by Harding in 1804.

423. Ceres is next to Juno. It was discovered by Piazzi on the first day of the present century.

424. Pallas is next to Ceres. It was discovered by Dr. Olbers in 1802.

Observation 1. The orbit of Pallas differs from those of all the other planets, in the greatness of the angle it makes with the ecliptic. This angle is nearly 35 degrees.

2. These four planets are called *asteroids*. They are so small, that they can only be seen by means of telescopes. They are supposed by some to be fragments of a large planet.

425. Jupiter is the largest planet of the system, being about 1400 times as large as the earth. His diameter is 89,000 miles.

426. Jupiter revolves round the sun in a little less than 12 years; on his axis in 9 hours 56 minutes.

427. Jupiter is the brightest planet next to Venus; when seen by a telescope, several belts are observed around its surface, parallel to its equator.

428. Jupiter is attended by four moons, which are frequently eclipsed by the shadow of the planet falling upon them.

429. The eclipses of Jupiter's satellites have been very useful in determining the longitudes of places, and the velocity of light.

430. Saturn is nearly twice as far from the sun as Jupiter is. It was considered the remotest planet of the system, till the discovery of Herchel in 1781.

431. The diameter of Saturn is 79,000 miles; it revolves round the sun in about 29½ years, and on its axis in 10 hours 16 minutes.

432. When viewed through a telescope, the body of Saturn is observed to be surrounded by a broad and thin *ring*, which is entirely detached from the body of the planet. This ring

is opaque, and shines by reflecting the sun's light.

Observation. The ring of Saturn is found to consist of two concentric rings, entirely separate from each other. The rings revolve on an axis from west to east in 10 hours 32 min. When the ring is edgewise to the earth, it appears like a line over the body of the planet. At other times it appears elliptical. Stars have been seen between the ring and the body of the planet.

433. Saturn has seven satellites of different sizes, and its body is surrounded also by belts, like those of Jupiter.

434. Herschel was discovered by the celebrated Dr. Herschel in 1781. It was by him named *Georgium Sidus.* It is also sometimes called Uranus.

435. The diameter of Herschel is 35,000 miles. It revolves round the sun in a little more than 84 years. Its revolution on its axis has not been ascertained.

Observation. Herschel's distance from the sun, is about 1800 millions of miles, being about twice as far as Saturn. Light, moving at the rate of 200 thousand miles in a second, is about two and a half hours in coming from Herschel to the earth.

436. The Herschel planet can rarely be seen but by means of a telescope. It is attended by six satellites.

437. Comets, like the planets, revolve about the sun.

438. They move in eccentric ellipses, and the periods of their revolution are so long that only three are known with any degree of certainty.

439. Comets are only visible to us when they are in that part of their orbit which is nearest to the sun, and then they move so fast as soon to become invisible again.

Observation. The tail of a comet is always turned from the sun.

440. Comets are opaque bodies like the planets, and shine by reflecting the sun's light.

441. The number of comets belonging to the system, is not known; but it is supposed to amount to several hundreds.

442. The appearance of a comet is usually that of a collection of vapour, in the centre of which is a *nucleus*, which is, in most instances, not very distinctly defined.

443. When a comet first appears, its nucleus is sorrounded by a faintly luminous vapour, to which the name of *coma* has been given. As the comet approaches the sun, the *coma* becomes more bright, and at length shoots out into a long train of luminous transparent vapour, in a direction opposite the sun. This forms the *tail* of the comet. The tail is always transparent, so that stars may be seen through it.

Observation. The apparent *length of the tail* depends upon its direction with regard to the spectator. If it go towards or from him, it will appear shorter.

OF THE FIXED STARS.

444. The Fixed Stars are so called, because they do not change their places with regard to one another, as the planets do.

445. They are commonly classed into seven magnitudes; the largest are called stars of the first magnitude, and the smallest those of the seventh.

446. Although the number of stars appears to us as innumerable, this is a deception; occasioned probably by the refraction and reflection of the rays of light passing from them through our atmosphere.

447. There are seldom more than a thousand stars visible at any one time.

448. The stars are divided into groups or constellations, called by the names of animals and other objects which they are supposed to resemble, such as the Great Bear, the Eagle, Swan, &c.

449. The fixed stars, from their immense distance, must shine by their own light, and

are probably suns like our sun, to different systems of planets.

450. Many of the fixed stars, which to the eye appear as single stars, are found to consist of two.

451. There are also clusters of stars called *nebulæ;* the most remarkable of these is that broad zone called the Milky Way.

452. According to Dr. Herschel, each nebula is composed of a prodigious number of suns, and each sun is destined to give light to a system of worlds that revolve about it.

453. Stars which are only visible by the help of a telescope, are called *telescopic stars.*

454. The largest stars are not found to have any sensible disc, even when viewed through a telescope of high magnifying power.

Observation 1. Dr. Herschel, with his forty feet telescope, thought he observed a diameter to Lyra of about half of a second. He says also, that with this telescope he observed clusters of stars 40,000 times as far off as Sirius. Now light is about three years in coming from Sirius to the earth, hence from stars 40,000 times as far off as Sirius, light would be 120,000 years in coming to the earth, or twenty times as long as since the creation of the world, If one of these stars were to be extinguished, it would continue to shine at the earth for 120,000 years after, by the light that was previously emitted from it. Sirius is supposed to be the nearest star to the earth.

2. When we look at any star, the light that falls on the eye has been at least three years on its way from the *star;* and we see the star, not where it is now, but where

it was at least three years ago, when the light left it which now falls on our eyes.

455. New stars sometimes appear, and others disappear. Several stars mentioned by the ancient astronomers, are not now to be seen; and several are now visible, which are not mentioned in the ancient catalogues.

Observation. Although the stars are called *fixed*, this is only to be understood as meaning that they do not change their position with respect to each other. Most astronomers of modern times believe, that they all have a motion about some distant centre.

456. The fixed stars do not shine with a steady light, like the planets; but they have a quivering, called the *twinkling* of the stars.

Observation 1 By this difference, a planet can be easily distinguished from a fixed star.

2. The twinkling of the stars may be accounted for as follows, viz. It has been shown to Optics, that the impression made by the light upon the eye continues for *some time*, but that it gradually diminishes. Now a fixed star having no visible diameter, only one stream of the rays that proceed from it, can enter the pupil of the eye; and as the stars are at such an immense distance, the particles of light that would fall upon so small a surface as the pupil of the eye, must be at a considerable distance from each other. When, therefore, a particle of light falls upon the eye, it produces a *vivid impression*, which becomes gradually dimmer until another particle arrives, producing a vivid impression again.

3. In this way, also, we may account for the deception in the number of stars visible to the naked eye on a clear

evening. The particles of light which proceed from more distant stars, falling upon the eye at too great intervals to keep up a continual image. when a particle of light falls upon the eye, it produces the perception of a star; and when we endeavour to contemplate this star, it is invisible; because the image formed has vanished, and other particles have not yet arrived to renew it.

4. Hence the reason why telescopes enables us to see stars that are invisible to the naked eye, is that they concentrate the rays from so large a surface, as to keep up a continual image of that star.

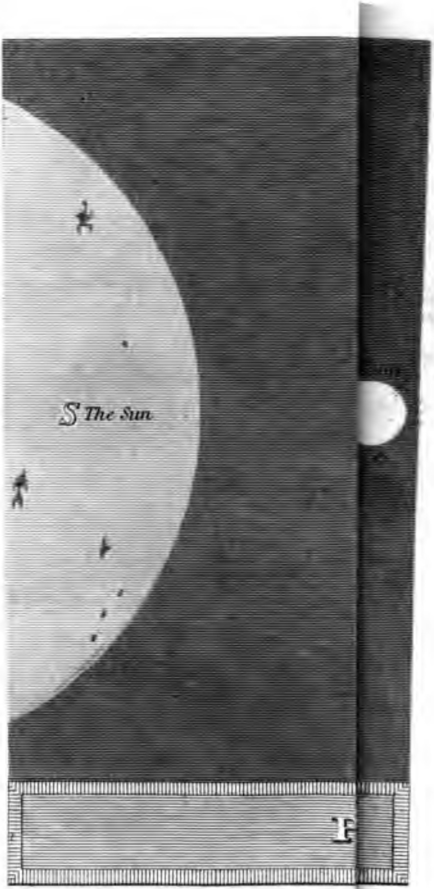
OF ECLIPSES.

457. When any heavenly body is obscured or darkened by the shadow of another falling upon it, or by the interposition of any body, it is said to be eclipsed.

458. The eclipses of the sun and moon are the most striking; and were formerly regarded as ominous of impending evil.

459. As the earth is an opaque body, enlightened by the sun, it will cast a shadow towards that side which is farthest from the sun.

Observation. The earth being so much smaller than the sun, its shadow must be in the form of a cone, having the earth for its base.


S The Sun

460. When the moon, in revolving round the earth, passes through the earth's shadow, it causes an eclipse of the moon.

Illustration. The moon shines by reflecting the sun's light. When the earth comes between the sun and moon, it intercepts the sun's light, and prevents it from falling on the moon; and hence the moon cannot shine.

461. An eclipse of the moon takes place when the sun, the earth, and the moon are in, or very nearly in a straight line, which is only at the *time of full moon.*

462. If the moon revolved round the earth, in the same plane or level in which the earth revolves round the sun, it is evident the moon would pass between the earth and sun at every new moon, and through the earth's shadow at every full moon. There would therefore be an eclipse of the sun and moon in every revolution.

463. The orbit of the moon is inclined to the plane or level of the ecliptic in an angle of about five degrees and a quarter. The places where the moon's orbit cuts the plane of the ecliptic, are called the *moon's nodes.*

464. On account of the inclination of the moon's orbit to that of the earth, an eclipse of the moon cannot take place at every full moon.

465. When the moon passes entirely *through the* earth's shadow, the eclipse is

total; when only a part of it passes through the shadow, the eclipse is *partial.'*

466. In a total eclipse of the moon, the rays of light from the sun, in passing through the earth's atmosphere, are refracted so as to fall upon the moon's surface and render it visible.

467. In an eclipse of the moon, the moon actually ceases to shine; hence all those who have the moon above their horizon may observe the eclipse.

Observation. The following eclipses of the moon will be visible and total at Washington:—

1. On the 21st of June, 1834. The eclipse will begin about twenty-three minutes after six in the evening, and continue three hours and thirty-five minutes.

2. On the 5th of February, 1841. The eclipse will begin about fifty-eight minutes after six in the evening, and continue three hours and thirty-two minutes.

3. On the 24th of November, 1844. The eclipse will begin about fifty-four minutes after four in the evening, and continue three hours and fifty-one minutes.

468. An eclipse of the sun is occasioned by the moon's coming directly between the earth and the sun, and thereby obstructing our view of the sun.

469. When the moon happens to be between the sun and earth at the time of new moon, there will be an eclipse of the sun.

470. As the moon is so much smaller than

the earth, only a small part of the earth's surface can, at the same time, experience an eclipse of the sun.

471. When the whole surface of the sun is obscured by the moon, the eclipse is *total.* When only part is obscured, it is *partial.* When a part of the sun's surface appears all round the moon, the eclipse is called *annular.*

Illustration. The moon revolves in an elliptical orbit round the earth, and is consequently farther from the earth at some times than at others. When nearest the earth, the moon's apparent diameter is greater than the apparent diameter of the sun; but when farthest from the earth, it is less; and therefore would not obscure the whole of the sun's surface, although it were directly between the spectator and the sun.

472. At the time of an eclipse of the moon to us, there would be an eclipse of the sun to a spectator at the moon.

Observation. When there is a *total* eclipse of the sun to any part of the earth, a spectator at the moon would observe a dark spot traversing the illuminated surface of the earth. In a partial or annular eclipse, this spot would not be dark, but only less brilliantly illuminated than the rest. This would be an eclipse of the moon to a spectator at the moon.

473. The greatest number of eclipses that can take place in a year is seven; and the least number, two.

474. When there are seven eclipses in a year, five are of the sun and two of the moon; when there are but two, both are of the sun.

Observation. The following eclipses of the sun will be visible at Washington:—

1. On the 20th of November, 1834. It will begin about one o'clock, and continue two hours and forty minutes. About eleven-twelfths of the sun will be obscured.

2. On the 15th of May, 1836. It will begin about seven o'clock in the morning, and continue nearly two hours and a half. About two-thirds of the sun will be obscured.

3. On the 18th of September, 1838. It will begin about nine minutes after three, and continue more than two hours and a half. This eclipse will be *annular*, the sun appearing in the form of a ring round the moon. There will not be such a phenomenon visible again at Washington during the present century.

4. On the 26th of May, 1854. It will begin about six minutes after four in the afternoon, and continue about two hours and twenty-four minutes. There will be about five-sixths of the sun obscured.

475. When any one of the heavenly bodies disappears by another body coming before it, it is called an *occultation.*

476. The *occultations* and approximations of the fixed stars by the moon are of use in determining the *longitudes* of places.

OF THE TIDES.

477. The ebbing and flowing of the sea are owing to the attraction of the sun and moon, but chiefly to that of the moon.

478. This attraction cannot alter the shape of the solid parts of the earth, but it has a great effect on the water, and causes it to assume a spheroidal figure, the longest axis being in the direction of the moon.

479. It is the highest tide at the place which is perpendicularly under the moon, or where the moon crosses the meridian.

480. The tide is at its greatest height, not when the moon is on the meridian, but some time afterwards; because the force by which the moon raises the tide continues to act for some time after it has passed the meridian.

481. The oval figure of the waters keeps pace with the moon in its monthly journey 'round the earth.

482. The earth, by its daily rotation upon its axis, presents each part of its surface to the action of the moon.

483. There are two tides in every place, in about twenty-five hours, because the action of the moon produces a tide in the place over which it passes, and also in the opposite surface of the globe at the same time.

484. The two tides that occur every twenty-five hours are not of the same height, except when the moon is on the equator. When the moon is north of the equator, she will cause the greatest tide in the northern hemisphere when she is above the horizon, and the greatest in the southern hemisphere when below the horizon; but when the moon is south of equator, it is *vice versa.*

485. When the action of the sun and moon conspire together, as at full and new moon, the tides are highest, and are called *spring* tides.

486. When they counteract each other, as in the quarters, they produce the lowest or *neap* tides.

Observation. The highest tides of all are at the new and full moon nearest the equator.

ELECTRICITY.

487. The earth and all the bodies with which we are acquainted are supposed to contain a certain quantity of an exceedingly subtle fluid, called the *electric fluid.*

488. The certain quantity belonging to all bodies is called their natural share, and produces no sensible effects.

489. When any body becomes possessed of *more* or *less* than its natural quantity, it is said to be *electrified*, and is capable of exhibiting certain appearances which are ascribed to the *power* of *electricity*.

Example 1. Take a stick of sealing wax and rub it with your hand or with a piece of flannel, or on your coat sleeve, and it will have the power of attracting small bits of paper or other very light substances when held near them.

2. If a clean and dry glass tube be rubbed several times upwards and downwards, and then presented to any small light substance, it will immediately attract and repel them alternately for a considerable time. The tube is then said to be *excited*.

3. If a glass tube be rubbed several times in the dark, and then brought within about half an inch of the finger, a lucid spark will be seen between the finger and the tube, accompanied with a snapping noise, and the finger at the same time will perceive the sensation of a prick from a pin. The attraction, repulsion, sparkling, and noise, are the effects of electricity, and are denominated electrical appearances.

4. If an oblong piece of metal, such as a poker, be suspended by means of a dry silk string, and the excited glass tube be presented to its upper end, then the lower end of the metallic body will exhibit the same phenomena as the tube itself, which shows that the electric fluid passes through the metal.

5. If instead of the metallic body, a stick of glass or sealing wax be suspended, none of these phenomena will be exhibited, which shows that the electric fluid does not pass through these substances.

490. All those bodies, which, like the me-

tallic substance, transmit electricity, are called *conductors* of that fluid.

491. Those substances that will not transmit the electric fluid are called *electrics* or *non-conductors.*

492. The metals, semi-metals, and metallic ores, are conductors of electricity; so also are charcoal, water and other fluids, excepting the aerial fluids and oil. Almost all saline and many earthy substances are conductors. Also highly rarified air and animal bodies are conductors.

493. The following substances are *electrics* or *non-conductors* of *electricity:* viz. vitrefied substances, precious stones, amber, sulphur, resinous substances, wax, silk, cotton, feathers, wool, hair, paper, elastic fluids, sugar, oils, metallic oxides,* animal and vegetable ashes, dry vegetable substances as baked wood, &c.

494. All substances become conductors when they are made hot.

495. When a body has more than its natural quantity of this fluid, it is said to be *positively* electrified; when it has less than its natural share, it is said to be *negatively* electrified.

496. When a conductor is so surrounded by

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* For the explanation and illustration of this and some other terms see An Easy Grammar of Chemistry.

non-conductors that the electric fluid cannot pass from it to the earth, it is said to be *insulated.*

Experiment. The human body is a good conductor of electricity, but if a person stand on a cake of rosin, or on a stool supported by glass legs, the electric fluid cannot pass from him to the earth.

497. The principal method of exciting the electric fluid is friction.

498. When a conductor and an electric are rubbed against each other, the electricity is the most powerfully excited: in this case the electric fluid passes from the conductor to the electric.

Experiment 1. If a smooth glass tube be rubbed with the hand, the electric fluid will leave the hand, and pass upon the tube, which will now have more than its natural quantity.

2. If the finger, or any conducting substance, be presented to the tube, the electricity will pass into it.

499. Two substances, both positively or both negatively electrified; *repel* each other.

500. Two substances, of which one is positively and the other negatively electrified, attract each other.

501. If the person who rubs a glass tube be insulated, both the person and the glass tube become electrified, and capable of attracting and impelling light bodies: but the electricity

of the person will differ from that of the tube, as the following experiment will show.

Experiment 1. Let two cork balls, connected by a linen thread, be held by a silk thread attached to the middle of the former, at some distance from a wall: then bring the excited tube near the balls, and it will first attract, and soon after repel them: this repulsion will continue for a considerable time, though the tube be removed.

2. Let another pair of cork balls be brought in contact with the insulated person, and they also will repel each other.

3. But if the two pairs of balls be brought near they will attract each other, and the electrical virtue will disappear; which shows that there are two electricities, one being the reverse of the other, and seeming to have what the other wants.

4. If the insulated person rub a stick of sulphur or rosin, or sealing wax, that substance will acquire the electricity which in the preceding experiment was acquired by the insulated man.

Cor. Hence, positive and negative electricity have been called *vitreous* and *resinous.*

502. These electricities always accompany each other, for if any substance acquires the one, the body with which it is rubbed acquires the other.

503. When one side of a conductor receives the electric fluid, its whole substance is instantly pervaded with it; whereas, when an electric is presented to an electrified body, it becomes electrified in a small spot only.

504. If to one side of an electric, viz. a

pane of window glass, you communicate positive electricity, the opposite side will be negatively electrified, and that plate is said to be charged.

505. The positive and negative electricities cannot come together, unless a communication by means of conductors is made between their sides.

506. When the two electricities are united, their virtues are destroyed, and the act of their union is called the *electric shock.*

507. Machines have been contrived for rubbing together electrics and conductors, and for collecting the electric fluid from surrounding bodies. These are called *electrical machines.*

Illustration. Fig. 54 represents an electrical machine of the simple sort. GEF is a strong board, which supports all the parts of this machine, and which may be fastened to a table by means of one or more iron or brass clamps, as Q: the glass cylinder AB is supported by the two glass legs, G and E. IR, is the rubber, and IRK, is a silken flap. This cushion or rubber is fastened to a spring which proceeds from a socket cemented on the top of the glass pillar S. The lower part of the pillar is fixed into a small board, which slides upon the bottom board of the machine, and by means of a screw nut and a slit at H, may be fixed more or less forward, in order that the rubber may press more or less upon the cylinder, NF is a glass pillar which is fixed in the bottom board, and supports the prime conductor ML, of hollow brass or tin plates, which has the collector, or pointed wires at L, and a brass knobbed wire at M. From the knob O a longer spark may be drawn than from any other part of the conductor. When the cylinder is turned swiftly, the friction of the glass against the rubber causes the electric fluid which was in the rubber to pass to the glass, from whence it is conveyed to the prime conductor, the points of which *a* are presented to every part of the cylinder in succession. If a chain be put on the knob *x*, the other end of which hangs on the ground, there will be a constant supply of the electric fluid to the prime conductor, which, if other bodies are presented to it, will keep discharging all the while in sparks. The rubber is supplied by means of the things in immediate contact, and these again are supplied by the general mass of the fluid that is lodged in the earth.

OF ELECTRICAL ATTRACTION AND REPULSION.

508. Bodies that are charged with the same electricity *repel* each other; but if one have more and the other less than its share, they will *attract* one another.

Experiment 1. If a tuft of feathers be hung on the prime conductor LM, fig. 54, the moment they are electrified by turning the wheel of the machine, they will endeavour to avoid one another and stand erect; because being all electrified by the same electricity, they repel each other.

2. A large feather will, if placed in the hole *z*, when the machine is worked, become beautifully turgid, expanding its fibres in all directions; and they collapse when the electricity is taken off by presenting any conducting substance to them.

3. Excite a glass tube 18 or 20 inches long, then present to it a small feather, which will first be attracted by it, and afterwards jump from it. If no other body happen to be in the way, it will tend towards the ground: but if the tube be held under it, it will be still repelled, and may be driven about for a considerable time.

4. Suspend a plate of metal from the conductor, and underneath it, at the distance of about three or four inches, put another plate of the same size; upon the lower one small feathers, pieces of paper, &c. may be placed, these will, as soon as the machine is worked, jump to the plate, from which they will be repelled, and fly to discharge themselves upon the lower plate, after which they will be attracted and repelled again.

5. If two balls, made of cork or of the pith of elder, about the size of large peas, be fastened to silk threads, they will hang parallel to each other, and be in contact; but when brought near the electrified prime conductor, they will strongly repel each other.

6. These balls, in their electrified state, show whether the electricity is positive or negative; for if it be positive, by applying an excited stick of sealing wax, the thread will collapse: but if it be negative, the sealing wax will make them recede still further.

509. A pair of cork or pith balls is used to discover the presence of the electricity, and is denominated an electrometer.

Example. Fig. 55 represents a *quadrant* electrometer, which may be fixed in the hole *z* of the prime conductor, fig. 54. It consists of a very light rod, and pith ball A turning on the centre of a semi-circle B. According to the strength of the electricity the pith ball flies off, and the scale marks the degree in which the prime conductor is electrified.

510. If a body containing only its natural

share of electricity be brought near a body that is electrified, positively or negatively, a part of the electricity in the form of a *spark* will force itself through the air, from the latter to the former.

511. When two bodies, one electrified positively, the other negatively, approach each other, the superabundant electricity rushes violently from one to the other, to restore the equilibrium.

512. If an animal be placed so as to form part of this circuit, the electricity in passing through it produces a sudden and violent effect, called the *electric shock.*

513. The motion of electricity in passing from a positive to a negative body is so rapid, that it appears to be *instantaneous.*

514. When any part of one side of glass is presented to a body electrified positively or negatively, that side of the glass becomes possessed of the *contrary* kind of electricity to the side of the body it is presented to, and the other side of the glass is possessed of the same kind of electricity as the other body.

Experiment. If the knob O of the prime conductor, fig. 54, be electrified positively, and a pane of glass be presented to the side next to O, it will be negatively electrified, and the other side will be positively electrified.

515. Electricity communicated to glass does not spread beyond the spot where it is

thrown, on account of its non-conducting quality.

516. Electricity may be communicated to the whole surface of glass, or any part of it, if it be covered with a metallic substance, as tinfoil. This is called *coating* the glass.

517. If a conducting communication be made between both sides of a glass thus *coated* and *charged* with electricity, a discharge takes place.

518. Glass of any form, provided it be sound, will answer the purpose, but cylindrical jars are chiefly used.

519. A glass bottle or jar properly coated for electrical purposes, is called a *Leyden* phial, or jar, from the place where this property was discovered.

Illustration. Fig. 56, represents a Leyden jar, coated with tin-foil on the inside and outside, within about three inches of the top of its cylindrical part, and having a wire with a round brass knob, or ball A, at its extremity. This wire passes through the cork or wooden stopple D; at its lower extremity is a piece of chain that touches the inside coating in several parts. To charge this jar, a communication is made between the electrical machine and the brass knob A, while the outside of the jar communicates with the earth by the table or the hand.

Experiment 1. Bring the knob A of the jar near the prime conductor, and after a few turns of the machine the jar will be charged: that is, the inside of the jar will be positively, and the outside negatively electrified: or if the inside is negatively, the outside will be positively electrified. R is a discharging rod, which is used to convey the superabundant electricity from one side to the other where there is less than the natural share. The discharging rod consists of two brass knobs *a a* attached to wires which move round a joint *x* fixed to a glass handle R.

2. When one of the knobs is applied to the ball A, and the other to the outside coating, a communication is made between the outside and the inside of the jar, by which the equilibrium is instantly restored by the superabundant electricity passing from one side to the other, appearing in the form of a vivid flash, accompanied with a loud report.

3. A shock may be taken by putting one hand to the outside coating, as at *a*, and bringing the other to the knob A.

4. Any number of persons may receive the shock together by taking hold of each other's hands, the person at one end touching the outside of the jar, and the person at the other end bringing his hand near the knob A. If there were a hundred persons so situated, they would every one feel the shock at the same instant. The electric fluid may be conveyed many miles in a moment of time.

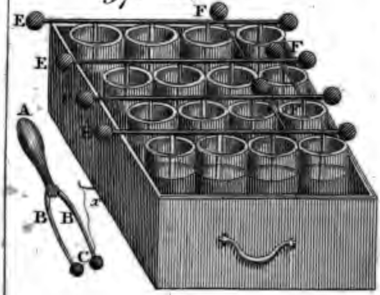
520. Several Leyden jars, connected together by making a communication between all the outsides, and another communication between all their insides, form an electric battery.

Illustration. Plate viii. fig. 57, represents a battery consisting of 16 jars, coated with tinfoil, and disposed in a proper box. The wires which proceed from the inside of every four of those jars, are screwed or fastened to a common horizontal wire E, which is knobbed at each extremity, and by means of the wires F, F, F, the inside coatings of 4, 8, or 12, or of all the 16 jars, may be connected. The inside of the box which contains these jars is lined with tin-foil. On one side of

Electricity &c.

VIII.

57 Battery



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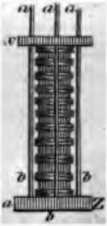

Galvanism

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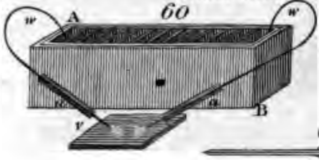

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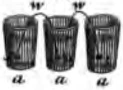

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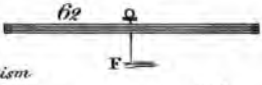

Magnetism

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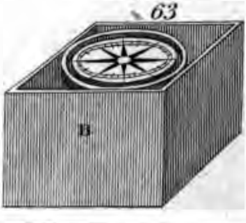

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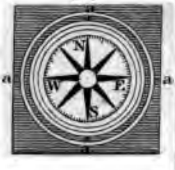


this box there is a hole, through which a strong wire or hook passes, which communicates with the lining of the box, and of course with the outside coatings of the jar. To this hook a wire is occasionally fastened, which connects it with one branch of the discharging rod BBCA.

521. Electricity, by means of the battery, is capable of producing the most powerful effects.

Example 1. A very slender wire, as *x*, being made part of the circuit, will by the discharge of the battery instanly become red hot. It sometimes melts into small globules of different sizes.

2. If between two slips of window glass some gold leaf be placed, and the slips of glass be pressed firmly together, and the shock from the battery be sent through them, the gold leaf will be forced into the pores of the glass.

3. If the gold leaf be put between cards, and a strong charge be passed through them, it will be completely fused.

4. Gunpowder may be fired by the electrical battery.

522. Metallic points attract the electricity from bodies silently, which renders them useful in defending buildings from *lightning*.

523. When electricity enters a point, it appears in the form of a star: when it goes out from a point, it puts on the appearance of a brush.

524. Instruments may be put in motion by the electric fluid which issues from a point; hence we have electrical orreries, mills, &c.

525. Lightning is the rapid motion of vast masses of the electric matter.

526. Thunder is the noise produced by the motion of lightning.

527. Heated air is a conductor of electricity, and for this reason a chimney that has fire in it, is more likely to be struck with lightning than one that has not.

528. Electricity is carried into the air during the process of *evaporation*. Hence, upon the rapid condensation of vapour, there is an accumulation of electricity.

Obs. 1. If a portion of water is suffered to evaporate from a glass vessel, what remains will be found to be in a negative state of electricity, which shows that the vapour has carried off more than its proportionate part.

2. Vapour being subject to more rapid condensation in summer than in winter is the reason why we have more lightning. When the condensation is gradual, the electricity is produced in such small quantities, as to pass quietly from one place to another.

529. When the electric fluid passes through highly rarefied air, it constitutes the *aurora borealis*, or *northern lights*.

530. Most of the great convulsions of nature, such as earthquakes, whirlwinds, hurricanes, &c. are generally accompanied with, and dependant upon, electrical phenomena.

GALVANISM.

531. The science of Galvanism appears to be another mode of exciting electricity: it derives its name from Galvani, who first discovered it.

532. Electricity, properly so called, is chiefly excited by friction; but the effects of galvanism are produced by the chemical action of bodies upon each other.

533. The nerves and muscles of animals are most easily affected by the galvanic fluid.

534. In 1791, Galvani of Bologna discovered that a dead frog may have its muscles brought into action by very small quantities of electricity.

535. He also discovered that the same motions may be produced in the dead animal, merely by making a communication between the nerves and muscles by means of conducting substances.

Exper. 1. If a living frog or a live fish, as a flounder, having a slip of tinfoil pasted upon its back, be placed upon a piece of zinc, whenever a communication is formed between the zinc and tinfoil, the spasms of the muscles are excited.

2. If a person place a piece of one metal, as a half crown, above, and a piece of some other metal, as zinc, below the tongue, by bringing the outer edges of these pieces in contact, he will perceive a peculiar taste.

3. If a person in a dark place put a slip of tinfoil upon the bulb of one of his eyes, and a piece of silver in his mouth, by causing these pieces to communicate, a faint flash of light will appear before his eyes.

536. The conductors of the galvanic fluid are divided into the *perfect* and *imperfect.*

537. The perfect conductors consist of *metallic substances* and *charcoal.*

538. The imperfect conductors are *water* and *oxydating fluids*, as the *acids*, and all the substances that contain these fluids.

539. The simplest galvanic combinations must consist of three different conductors, not wholly of one class. When two of the three bodies are of the first class, the combination is said to be of the *first order;* otherwise, it is said to be of *the second.*

540. It seems to be indispensably requisite, that in simple galvanic circles the conductors of one class should have some chemical action upon those of the other.

Experiment. If a piece of zinc be laid on a piece of copper, and a piece of card or flannel moistened with a solution of salt in water, and then three other layers in the same order, and so repeated several times, the whole will form a pile or battery of the *first* order.

541. When the three bodies which form a galvanic circle of the first order are laid upon one another, the upper and under one not touching, then these two extremes are in *opposite electric states.*

542. The galvanic effects may be increased to any degree by a repetition of the same simple galvanic combination.

543. These repeated combinations are called galvanic piles or batteries, which may be constructed of various forms.

Experiment. 1. Take a number, say 12. of plates of silver, and the same number of pieces of zinc, and also of woollen cloth, the last are to be soaked in a solution of sal-ammoniac in water: with these a pile is to be formed, as in fig. 58, viz. a piece of silver, a piece of zinc, a piece of cloth, and thus repeated. These are to be supported with three rods of glass *a b*, and pieces of wood *x* and *z*, and the pile is complete, and will afford a constant current of electric fluid through any conducting substance; thus, if one hand be applied to the lower plate, and the other to the upper one, a shock will be felt, which is repeated as often as the contact is renewed.

The plates will soon become *oxydated*, and require cleaning in order to make them act.

2 Another battery consists of a row of glasses of any shape, as *a a*, fig. 59, containing a solution of salt and water: into each of these, except the two on the outside, is put a plate of zinc *z*, and another of silver *x*; these plates communicate by means of the wires *w w*, and so fastened that the silver *x* in one glass is connected with the zinc *z* in the other; when one hand is dipped into the first glass and another in the last, a shock is felt. The glasses may be of any number.

3. The most convenient kind of battery consists of a trough AB, made of baked wood, three inches broad and about as deep; in the sides of the trough are grooves opposite to each other; into each pair of grooves is fixed, by cement, a plate of zinc and silver soldered together, and in the order of silver and zinc, the cement must be

filled in so as to prevent any communication between the different cells. The cells are to be filled with a solution of water and salammoniac: when a communication is made between the first and last cell, by means of the hands, a strong shock is felt. The shock is felt as often as the contact is renewed.

4. Several persons, by joining hands, having first wetted them with water, may receive the shock.

544. The spark from a powerful galvanic battery acts upon and inflames gunpowder, charcoal, cotton, and other inflammable bodies.

Experiment 1. Fill the battery, fig. 60, with water and nitrous acid, in the proportion of 9 parts of water and one of acid, and wipe the edges of the plates very dry, then the wires *w w* are to be fastened to pieces of copper and put into the outer cells; *a a* are little glass tubes to hold the wires by. Bring the wires together on the plate of glass *v*, and a spark will be perceived; if gunpowder be laid on the glass between the points of the wires, it will be inflamed.

2. Gold and silver leaf may be inflamed in this way: Dutch gold burns with a beautiful green light; silver with pale blue; gold with yellow light.

545. By galvanism many facts are explained in common life, which were unintelligible before.

Experiment 1. Porter is said to have a peculiar taste when drank out of a pewter vessel; here is a complete galvanic circle of the second order; the moisture of the under lip is one conductor of the second class, the porter is the other, and the pewter is the conductor of the first class.

2. Another galvanic circle is seen by the discolouration of a silver spoon in eating eggs; the saliva and fluid egg are conductors of the second class, and the silver of the first.

3. Pure mercury retains its splendour a long time, but let it be amalgamated with tin, and it is quickly oxydated.

4. Works in metal, the parts of which are soldered together, soon tarnish in the places where the metals are joined.

5. The nails and the copper in the sheathing of ships are soon corroded about the place of contact. These are the effects of galvanism.

546. Some fish, as the torpedo, the gymnotus electricus, and the silurus electricus, have the power of giving shocks similar to those produced by artificial electricity.

MAGNETISM.

547. Magnetism explains the properties of the loadstone, or natural magnet, which is a dark coloured and hard mineral body, and is found to be an ore of iron.

548. The magnetic properties may be communicated to other ferruginous bodies, which are thence called artificial magnets. These properties, however, act upon no substance but iron.

549. Natural and artificial magnets, as well as the bodies upon which they act, are either iron in its pure state, or such compounds as contain it.

550. All magnets attract iron.

551. When a magnet is at liberty to move itself freely, it constantly turns the same part towards the north pole, and the opposite part towards the south pole of the earth.

552. Those parts of the magnet's surface which it turns towards the poles of the earth, are called the north and south poles of the magnet.

553. The property of pointing to these poles is called its directive power; and when it places itself in that direction, it is said to traverse.

554. The magnetic meridian is a plane, perpendicular to the horizon, and passing through the poles of the magnet when standing in their natural direction.

555. The declination of the magnet, or of the magnetic needle, is the angle which the magnetic meridian makes with the meridian of the place where the magnet stands.

556. The north or south poles of two magnets repel each other; but the north pole of one attracts the south pole of another.

557. The inclination or dipping of the magnetic needle expresses the property which the

magnet possesses, of inclining one of its poles towards the horizon, and elevating the other pole above it.

558. Any magnet may, by proper methods, be made to impart its properties to iron or steel.

559. When a piece of iron is brought within a certain distance of one of the poles of a magnet, it is attracted by it; the attraction is strongest at the poles.

560. The magnetic attraction is not in the least diminished by the interposition of any bodies, except iron.

561. Soft iron is attracted by the magnet more forcibly than steel; but is not capable of preserving the magnetic property so long.

562. Heat weakens the magnetic power, and a great heat destroys it.

563. The addition of weight to a magnet, kept in its proper situation, increases the magnetic power.

564. The north pole of a magnet is more powerful in the northern, and the south in the southern parts of the world.

565. When a magnet with two poles is freely suspended or floats upon water, with no iron near it, places itself in the magnetic meridian, and it is this principle that makes so useful to seamen.

566. When a magnet is kept freely s

pended so that it may turn north and south, the pilot, by looking at its position, can steer his course in any given direction.

567. An artificial magnet fitted up in a proper box is called the *magnetic needle*, and the whole together is called the *mariner's compass*. See figs. 61.—64.

568. Though the north pole of the magnet always points toward the northern, and the south towards the southern parts, yet that direction is seldom in the exact direction of the poles of the earth, that is, the magnetic and the real meridian seldom coincide, and the angle which they make is called the angle of the declination of the magnetic needle.

569. This declination is said to be *east* or *west*, according as the north pole of the needle in eastward or westward of the true meridian of the place.

570. At present the declination of the magnetic needle is about 2 degrees westward.

571. If a magnetic needle be accurately balanced and suspended so as to turn freely in a vertical plane, the north pole will be depressed, and the south pole elevated above the horizon, this is called the *dip of the needle.*

572. A magnetical needle constructed for the purpose of showing this property, is called a *dipping needle.*

573. When a piece of iron is brought suf

ficiently near a magnet, it becomes itself a magnet.

574. Bars of iron that have stood long in a perpendicular situation are generally found to be magnetical.

575. If a long piece of hard iron be made red hot, and then suffered to cool in the direction of the magnetical line, it becomes magnetical.

576. The electric shock will often render iron magnetical; so also will lightning.

577. Artificial magnets as made by applying one or more powerful magnets to pieces of hard steel.

578. The power of a magnet is not diminished by communicating its properties to other bodies.

579. Two or more magnets joined together may communicate a greater power to a piece of steel than either of them possesses singly.

580. A magnetic needle is made by fastening the steel on a piece of board, and drawing magnets over it, from the centre outwards.

Illustration. A magnetic needle is represented in figs. 61 and 62, the first of which shows the upper side, and the second a side view of the needle, having a pretty large hole in the middle, to which a conical piece of agate is adapted by means of a brass piece O, into this the agate cap (as it is called) is fastened. The apex of the hollow cap rests upon the point of a pin F, which is fixed in the centre of the box, and upon which the needle, being properly balanced, turns very nimbly.

A mariner's compass is represented in fig. 63, the box which contains the card or fly with the needle, is made of a circular form, and either of wood, or brass, or copper. It is suspended within a square wooden box B, by means of two concentric circles, called gimbalds, so fixed by cross axes *a*, *a*, *a*, *a*, fig. 64, to the two boxes, that the inner one, or compass box, shall retain an horizontal position in all motions of the ship, whilst the outer or square box is fixed with respect to the ship. The compass box is covered with a pane of glass, that the motions of the card may not be disturbed by the wind. What is called the card, is a circular piece of paper, which is fastened upon the needle, and moves with it. The outer edge of this card is divided into 360 equal parts or degrees, and within the circle of these divisions it is again divided into 32 equal parts or arcs, which are called the points of the compass, or rhombs, each of which is often subdivided into quarters.

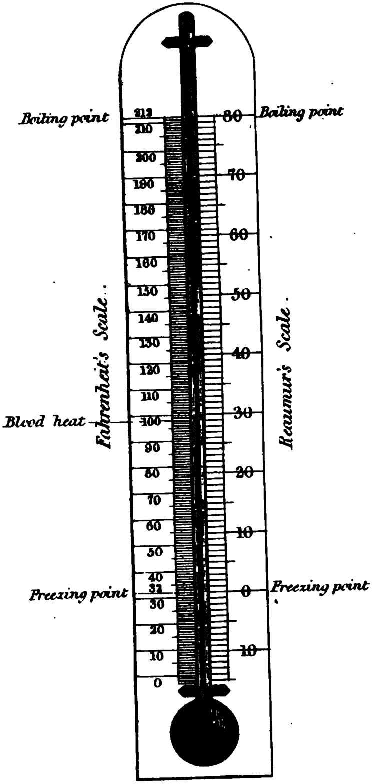
ON HEAT OR CALORIC.

581. *Heat*, or *Caloric*, is a very subtile fluid, capable of insinuating itself between the particles of the most dense bodies.

Obs. Heat is generally applied to the sensation produced by hot bodies ; and *Caloric* to the *cause* of that sensation. Heat is, however, sometimes used as the *cause* as well as the *effect*.

582. Caloric is supposed to be the only real fluid, and the general solvent of all other bodies; because any other body, as far as we

Thermometer.



are able to try, becomes a fluid by combining with a sufficient quantity of caloric.

583. All the effects of *heating* may be reduced to an enlargement of the bulk, or to the separation of the parts, of all sorts of bodies: and all the effects of *cooling*, to the contraction of the bulk.

Obs. Were it not for *heat*, there could be no fluid—no air, water, blood, or sap, &c.—every thing would be perfectly solid. Hence we see how entirely dependent we are upon heat.

584. *Heat* and *cold* are only relative terms; for the same body may feel cold to one person and hot to another, or it may feel both hot and cold to the same person.

Exp. Place one hand in hot water, and the other in snow, and then put both in water of middling temperature. This water will feel warm to the hand that was in snow, and cold to the hand that was in hot water.

585. *Cold* is only the *absence of heat;* and bodies cool by the heat passing from them. When a person feels cold, it is in consequence of the heat leaving his body.

586. Heat expands or increases the bulk of all bodies, and when bodies *cool*, or the heat leaves them, their bulk contracts again. Hence heat always tends to overcome the attraction of cohesion.

Obs. 1. By adding heat to ice, it becomes water; by adding heat to water, it becomes steam or vapour; and by increasing the heat of this vapour, it may be expanded without limit. On the contrary, if heat be taken from vapour, it becomes water; from water, it becomes ice; and the ice becomes more and more solid, in proportion as the heat is taken from it.

2. Mechanics frequently make use of the property of heat in expanding bodies. In hooping a wheel, for instance, they first heat the hoop, and put it on the wheel in this expanded state, then when it cools it contracts, and becomes very tight.

587. When any body is compressed, or in any manner condensed, heat is given out to the surrounding bodies.

588. When substances expand, they absorb heat from the surrounding bodies, and those bodies will thereby be cooled.

Obs. Bodies in passing from a rarer into a denser state, always give out heat; but in passing from a denser into a rarer state, they absorb heat.

Exp. 1. When a person's hands are wet, they feel colder than when dry, because the water that is upon them is converted into vapour and carries off the heat.

2. When a piece of metal is hammered, it becomes warmer, because it is rendered more dense.

3. When in mixing two fluids, as water and sulphuric acid, the bulk of the mixture is less than the bulk of the ingredients, heat is produced.

589. Heat has a natural tendency to *equilibrium;* that is, if a hot body be placed among colder ones, the heat will gradually pass from

it to *them*, till they all become of the same temperature.

590. Heat passes through some bodies quicker or easier than it does through others; hence the former are said to be *better conductors* of heat than the latter.

Obs. 1. The metals are the best conductors, and dense stones the next. Fur, wool, cotton, silk, wood, charcoal, &c. are bad conductors. In general, the denser a body is, the better it conducts heat, and *vice versa.*

2. Bad conductors, as fur, wool, cotton, &c. are best for clothing in winter, and good conductors, as linen, &c. for summer.

3. In warm weather, ice wrapped in fur, woollen, &c. melts much more slowly than when exposed to the air, because they prevent the heat of the atmosphere from passing to the ice.

591. When bodies are colder than the hand, a good conductor will always feel colder than a bad one of the same temperature, because it conducts the heat more rapidly from the hand. The sensation of heat and cold is always in proportion to the quantity of caloric that enters or leaves the hand in a given time.

592. When bodies are hotter than the hand, a good conductor will always feel hotter than a bad one of the same temperature, because it suffers more heat to enter the hand in a given time.

Exp. Hold a purse containing money near the fire. the money will soon become so hot as not to while the purse feels scarcely warm. The money being a good conductor, suffers the heat to pass rapidly into the hand; while the purse, which is a bad conductor, retains the heat. A thermometer would show them to be of the same temperature.

593. Some bodies absorb more heat than others, though placed in precisely similar situations. Hence different bodies are said to have different capacities for heat, that is, the same quantity of caloric will raise the temperature of one body more than that of another.

Exp. If a pound of water at 60° be mixed with a pound at 120°, the mixture will be 90°. If a pound of water at 60°, be mixed with a pound of quicksilver at 120°, the mixture will be only 62°; but if the water be 120°, and mercury 60°, the mixture will be 118°, which shows that water has a much greater *capacity* for heat than quicksilver. The *denser* a body is, the less capacity it has for caloric, and *vice versa.*

594. Every body is susceptible of different states by its combination with a greater or smaller quantity of caloric.

Illus. Ice is a combination of *solid water* with a certain quantity of caloric; *fluid water* is combined with a greater quantity of it, and vapour with a still greater quantity.

595. *Combined* caloric is that which enters into combination with any body, and is necessary to its existence in *that state.*

Illus. 1. The heat that is added to ice to convert it into water, is called the *combined heat* of the water; if it be taken away, the water is converted again into ice.

This is also called latent heat, because the water with which the heat is combined, is no warmer to the feelings, nor does a thermometer indicate any more heat in it than in the ice.

2. *Fluids* are only solids combined with a portion of caloric; and vapours, fluids combined with an additional portion of caloric. Hence *vapours* contain more latent, or combined heat, than *fluids*, and fluids, more than solids.

3. Since heat is necessary to convert a solid into a fluid, or a fluid into vapour, when a vapour passes into a fluid, or a fluid into a solid, its combined or latent heat is given out. Hence, during the freezing of water, heat is given out to surrounding bodies, and during evaporation heat is absorbed from surrounding bodies, and they are cooled.

596. *Free caloric* is that portion of it which is *not combined* with any body, but which is ready to pass to surrounding bodies; and the quantity of it in any body is called the *temperature* of that body.

Illus. The free caloric in any body is that portion of it which may be taken away without altering the *state* of the body.

597. *Thermometers* are instruments constructed to show the temperature of a body, or the relative degrees of free caloric in a body by the expansion of fluids. The fluids mostly used for thermometers are mercury and spirits of wine.

598. Differently constructed thermometers have different names, generally from their inventors, as Fahrenheit's, Reaumur's, &c.—Fahrenheit's is generally used in this country.

Illus. 1. To construct a mercurial thermometer upon Fahrenheit's plan, take, a small tube with a bulb at one end, and when partly filled with mercury, apply the heat of a lamp to the bulb till the mercury boils, and fills the upper part of the tube with the mercurial vapour. Then hermetically seal the upper end of the tube, and withdraw the heat, and the vapour will condense, leaving a vacuum in the upper part of the tube. Immerse the bulb in a mixture of snow and common salt, and mark the place opposite the surface of the mercury 0 or zero. Next place the bulb in melting ice or snow, and mark the place opposite the surface of the mercury 32°, which is called the *freezing point* of water. Then place the bulb in boiling water, and mark the place opposite the surface of the mercury 212°, which is the *boiling point.* Divide the space between 0 and 32° into 32 equal parts or *degrees*, and continue these equal divisions about 40° below 0, which is the *freezing point of mercury.* Also divide the space between 32° and 212° into 180 equal parts, and continue these equal divisions upwards to about 600°, which is the boiling point of mercury.

2. In Reaumur's thermometer, 0 is placed at the freezing point, and 80° at the boiling point, and the intermediate space divided into 80 equal parts, which equal divisions are continued below the freezing point, and above the boiling point.

599. Fluids do not expand equally with an equal increase of temperature. Mercury expands more equably than any other fluid.

600. The higher the temperature of a body is, the more it is expanded by a certain quantity of caloric.

Obs. 1. The reason of this is, that when heat expands bodies, the attraction of cohesion, the only force counteracting the expansive force of heat, continually diminishes.

2. Water is supposed by some to *expand* by a decrease of temperature from about 40°, but this anomally is very doubtful. Several bodies, however, expand in congelation, and water is a remarkable instance of this..

3. The reason that water expands upon being frozen is, that it disengages the air contained in it, which forms the numerous cavities in the ice, and also that the particles assume a different arrangement requiring more room.

4. A vessel containing water seldom fails to be broken when the water freezes.

601. Under the usual pressure of the atmosphere, water cannot be heated beyond 212°, the additional heat converts a certain portion of the water into vapour, and is thus carried off.

Observation. Water is about 2000 times as dense as vapour. When a quantity of water is suddenly converted into vapour, as by dropping it into boiling oil or melted metal, it produces an immense explosion, scattering the oil or metal in all directions.

602. Water heated in a strong, closed vessel, where the vapour is prevented from going off, may be rendered so hot as to melt lead and dissolve bones. A vessel fitted for this experiment is called *Papin's digester*, from its inventor.

603. The more the pressure upon the surface of the water is diminished, the more rapidly is the water converted into vapour.

Illustration 1. Water boils at a much less temperature on the top of a mountain, or under the exhausted receiver of an air pump, than under the usual pressure of the atmosphere.

2. The expansive force of water, at any particular temperature, is capable of overcoming a certain pressure, and when the air is removed, the water will evaporate, till the pressure of the superincumbent vapour is equal to the expansive force of water at that temperature. Hence evaporation does not entirely depend upon the air.

604. Sea water freezes at about zero. A quantity of sea water is never all frozen, but the fluid part contains more salt and is more nauseus than the frozen part.

Observation 1. If what first freezes be melted and again subjected to cold, a part of it will freeze, which will contain less salt than what formerly froze; by repeating this process a few times, salt water may be purified.

2. By exposing *spirits* to a great degree of cold, the watery parts will freeze, while the part that remains liquid is much stronger; if this be again exposed to cold, a part of it will freeze, and the remaining part will be still stronger. In this way spirits may be concentrated.

605. All the heat we experience is derived from three sources, viz. 1st, from the *sun;* 2dly, from *compression*, which comprises collision and friction; 3dly, from the decomposition and composition of bodies, which comprehend combustion, fermentation, &c.

606. No sensible heat is known to be derived from any celestial body except the sun.

Observation. The moon, as it reflects so much light, might be expected to communicate some degree of heat, but the nicest experiments have not detected any. It has been calculated that the direct light we receive from the sun, is more than one hundred thousand times as dense as what is reflected to us from the full moon, and the heat is supposed to be in the same proportion.

607. *Compression*, which includes collision, and friction, is the more generally used source of heat, and the communication of the heat thus produced to combustible matters, produces that decomposition which is commonly called *fire.*

Observation 1. Solid bodies rubbed or knocked against each other are thereby heated, and often so far as to become very hot.

2. The heat from compression is produced by the parts being pressed nearer together, which increases the *density* of the body, and thereby diminishes its *capacity* for caloric; consequently, a portion of heat must be given out or rendered free, which communicates itself to the surrounding bodies.

608. Substances which are not compressible are not heated by mechanical force.

Illustration 1. A flint will only be *broken* by the stroke of a hammer, but a piece of iron may be rendered red hot in a little time. *Water* being nearly incompressible, is not altered in temperature by pressure, but *air* is very considerably.

2. When iron or any other metal is extended by hammering, rolling, &c. though previously cold, it becomes hot, *and in a short* time becomes rigid, and ceases to extend.

If it be then heated in a furnace, and allowed to cool gradually, its former pliancy is restored. This process is called *annealing*.

609. The third developement of heat arises from mixture, or from the composition and decomposition of bodies.

Illustration 1. Acids or spirits of wine, on being mixed with water, become hot; also a great variety of other bodies, on being mixed, become more or less hot.

2. It is not every mixture that becomes hot, but whenever a mixture is attended with heat, it is found that the bulk of that mixture is less than the sum of the bulks of the separate ingredients. Consequently, a condensation takes place, which diminishes the capacity of the body for caloric, and thereby liberates a portion of it.

610. The *heat* produced during combustion arises from the oxygen of the atmosphere, which unites with the cumbustible or burning body, and in thus passing from a rarer to a denser state gives out caloric.

Observation 1. The light produced during combustion, arises from the decomposition of the combustible body. It was shown in optics, that light is absorbed by vegetables while growing; it is indeed a necessary ingredient in them; when therefore they are decomposed, as by burning, this light must be liberated.

2. All animal substances are composed of vegetables; hence the light, which is a constituent of *vegetables*, must also be of *animals*; whence the liberation of light in the burning of candles, &c.

611. Fluids are exceedingly *bad conductors* of heat, if they are not perfect *non-conductors.* Heat is propagated through fluids merely by the internal motion of their particles.

Illustration 1. The particles of air which come in contact with a heated body, become specifically lighter than the surrounding air, and of course ascend; other particles of air then come in contact with the heated body, and they also are heated and ascend, &c. Hence the upper part of a room in which there is fire, or where there are a number of persons, is warmer than the lower part.

Experiment. Place a candle in the upper part of an open door of a warm room, and the flame will be bent out by the warm air going out. Place it at the bottom, and the flame will be bent in by the cold air coming in; place it about midway, and the flame will be erect.

Illustration 2. When a vessel of water is placed over a fire, the particles at the bottom become heated, and thereby lighter, and ascend, while colder and heavier particles take their place. In this way there is a continued internal motion, till the whole arrives at the temperature of 212° or to the boiling point. If the heat then be continued, a portion of the water at the bottom will be converted into vapour, and rise rapidly through the water, in the form of a bubble, causing what is called the boiling of the water.

612. When the surface of water is exposed to cold air, the upper particles are cooled, become heavier and descend, while warmer ones take their place; these are then cooled, and descend, &c. Thus a continual motion is carried on, till the whole becomes cooled to about 32°, when a portion of it freezes.

Observation 1. It is evident that water in cooling continually gives off heat to the air, which is the reason that places, as Britain, Ireland, &c. which are surrounded by water, have not so cold weather as places in the same latitudes at a distance from water.

2. When a body of water is deep, since warmer particles would be continually presented to the surface, the whole of it would not be cooled to the freezing point during the winter; this is the reason that deep lakes do not freeze.

613. A heat applied at the surface of water will descend but a little way. The surface of water in a vessel may be made to boil, while ice remains at the bottom.

Observation. Large fires are frequently made upon ice with safety.

614. Water, at the instant of passing into a state of ice, gives out a great quantity of heat.

615. Whatever obstructs the free motion of the particles of a fluid, obstructs the propagation of heat through it.

Illustration. Water that is thickened with any thing, cannot be heated so soon as clear water.

616. Caloric proceeds from a heated body in straight lines in all directions. This is called *radiant heat.*

Observation 1. The rays of *heat* are not the same as the rays of light, for we find some bodies give out a great deal of light without any sensible heat, others give out a great *deal of* heat with but little light.

2. The quantity of caloric radiated from a body in a given time, appears to be in proportion to the elevation of the temperature of the body above that of the surrounding medium.

617. When rays of heat fall upon any surface, they are either reflected, absorbed, or transmitted.

Observation. Generally these three effects are produced at the same time, but every body produces some one of them stronger than the other.

618. The surfaces of all bodies reflect, in greater or less quantities, the rays of heat that fall upon them. Polished surfaces, especially of metallic substances, reflect them best. The angle of incidence is always equal to the angle of reflection.

Observation. Hence, by means of concave reflectors, heat may be converged to a focus like light. Glass reflects light best, but metals reflect heat best. A finely polished metal is not sensibly heated by the rays of heat that fall upon it.

619. Bodies of the darkest colour, greatest capacities for caloric, and roughest surfaces, absorb most heat.

Experiment. When the ground is covered with snow, take four pieces of cloth, black, blue, brown, and white, of the same size, and place them near each other on the snow where the sun shines. In a few hours the black cloth will have sunk considerably below the surface, the blue not so much, the brown still less, and the white not at all, which shows that the black absorbs much the most heat, the blue less, &c.

Observation. Of opaque bodies, those which reflect least heat absorb most. Transparent bodies, as air, &c. are not heated by the rays of heat passing through them. The air is heated by coming in contact with warmer bodies.

620. Those bodies which absorb most heat, radiate most.

Corollary. The blacker and rougher a vessel is in which any thing is to be heated, the sooner it will heat, because it then *absorbs* more heat; on the contrary, the more finely polished and brighter a vessel is, in which any thing is to be kept hot, the better, because it will then radiate less.

621. The rays of heat are refracted like the rays of light, in passing obliquely from one medium to another. Hence the construction of burning glasses, &c.

Observation. When the sun's rays are refracted by a prism, Dr. Herschel found, that the greatest heat is entirely without the spectrum, just beyond the red rays, and that the heat decreased each way from that point.

622. *Animal heat* is that by which the human body and the bodies of other animals are kept warm, and enabled to communicate warmth to surrounding bodies.

Observation 1. Animal heat is occasioned by the oxygen of the atmosphere, which is inhaled by breathing, combining with the blood, and thus passing from a rarer to a denser state. The blood of fish, &c. which do not breathe, *is cold.*

2. When the blood is made to circulate more rapidly, as by the exercise of running, we breathe more frequently, and thereby our bodies become warmer.

623. A person feels cooler in a current of air, because the air which is warmed by his body is removed from around him, and a cooler portion brought in contact with him; and also because the evaporation of the moisture from his skin is promoted, which carries off the heat of the body.

Observation 1. In damp weather the same heat is much more oppressive, because the perspiration is not evaporated.

2. In consequenee of a provision of nature to obviate the pernicious effects of a great change of temperature, men have been exposed to a temperature on one extreme where mercury would freeze, and on the other extreme to a temperature above that of boiling water, without the temperature of the body being much changed.

624. A certain temperature is necessary to maintain vapour in the air, hence, when the temperature of air containing moisture is diminished, the moisture is precipitated.

Illustration 1. In warm weather moisture is precipitated on the outside of a pitcher containing ice water. The warm air coming in contact with the cold pitcher parts with its caloric, and consequently the water is precipitated.

2. When a current of warm air meets a current of colder air, the moisture is partially precipitated, forming clouds. In this way a person's breath in cold weather is rendered visible. Steam is perfectly transparent, but when it meets with colder air, the moisture is partially condensed and becomes visible.

625. When the atmosphere undergoes any considerable change of temperature, the consequent precipitation of the moisture contained in it is so great, that it descends in drops called *rain*.

626. In the evening the surface of the earth cools rapidly by the radiation of heat, and the warmer air coming in contact with it, is condensed, and moisture is precipitated forming *dew*.

627. Snow is frozen vapour. As vapour in freezing must give out a great portion of heat, the atmosphere becomes warmer while it is snowing.

628. Hail is occasioned by the freezing of the drops of rain in falling through the air.

Observation. The hail which frequently falls during very warm weather, may be accounted for as follows: It occurs only when there is an excessive accumulation of electricity in the atmosphere. Two clouds, highly charged in opposite electric states, coming within the electric influence of each other, displace the air, which is a non-conductor, from between them, so as to form a passage for the electric fluid while the moisture remains. This sudden displacement of the air produces such a degree of cold, as not only to freeze the vapour, forming the nucleus of the hail, but to reduce the temperature of that frozen vapour far below the freezing point. When, therefore, the warm air comes in contact with this frozen vapour, the moisture is precipitated upon it and freezes, and in this way the hail is increased as it falls to a very great size. Sometimes the temperature of the hail is so raised before it reaches the ground, by the constant precipitation of moisture upon it, that it is melted and falls in extremely large drops.

APPENDIX.

OF THE GLOBES.

For the common purposes of geography, it is usual to represent the surface of the earth on a plane. But, as the earth is nearly spherical in its form, no representation on a plane surface can give so accurate an idea of the relative situations of the different countries, oceans, islands, cities, &c. as can be given by delineating them on the surface of a sphere, according to their situations on the earth. It is true, the earth is not a perfect sphere, the equatorial diameter being about 25 miles greater than the polar diameter, as was stated in the observations on astronomy. The earth is also diversified with mountains and valleys, which form a very irregular surface, compared with the extent of our view, even when we are placed in the most favourable situations. But this difference in the diameters, and these irregularities in the surface of the earth, are so exceedingly small, compared with the whole magnitude of the earth, that they would scarcely be perceptible even on a globe of six feet diameter. The difference in the diameters would be less than one fourth of an inch, and the representation of the highest mountain would be smaller than an ordinary grain of sand. If the sphere be reduced to one third, or one fourth of this diameter, which is more nearly the size of ordinary globes, these irregularities would entirely disappear, and the difference between the polar and the equatorial diameters would not be appreciable. Hence we may conclude that, without extending it to an unmanageable size, a perfect sphere is the most accurate representation that can be given of the figure of the earth.

The artificial sphere or globe is constructed in the following manner:—A spherical block or mould of wood, somewhat less than the size of the intended globe, is prepared, and on it are laid successive coverings of paper or pasteboard, attached to one another by glue or paste till the whole is about one tenth of an inch in thickness. When completely dry, this covering is cut into two hemispheres, and is then easily separated from the mould. These hemispheres being placed on a wooden axis, representing the polar diameter, are stitched together in the same position as when attached to the mould. In the extremities of the wooden axis, are fixed pins of iron or some other metal, which represent the poles, and by which the whole is suspended in a metallic semicircle, whose diameter is equal to that of the intended globe. In this state, a composition of whiting and glue is applied to the surface of the paper, the globe in the mean time being made to revolve, so that the inner edge of the semicircle, which is prepared for the purpose, pares off the superfluous plaster from the projecting parts of the surface. The whole being thus made perfectly smooth and spherical, and at the same time so balanced on its axis, as to remain in any position it may be placed when suspended by the poles, it is set aside to dry and harden; after which it is ready to receive the different circles that are supposed to be drawn on the earth's surface, as well as a delineation of the different continents, islands, and oceans. The manner in which these are applied to it, will be described hereafter. The iron pins in the extremities of the axis, formerly used for fixing the globe in the metallic semicircle, are now employed to suspend it in a brass circle of such a diameter that the globe may just have room to revolve in it, without coming in contact with any part of its interior edge. This ring of brass is called the *universal meridian,* because by turning the globe it may be made to represent the meridian of any place. The top of the frame in which the globe is placed, always consists of a broad horizontal ring of wood of which the interior diameter is just equal to the interior diameter of the brazen meridian. The latter, with the globe suspended in it, passes through notches in the horizontal ring, and rests by its under edge in a metallic groove in which it may be made to slide, so as to elevate or depress the poles, at pleasure. In every position, however, one half the globe is above, and the other half below the upper surface of the horizontal ring. This surface, then, represents the *rational horizon.*

On the surface of the rim representing the rational horizon, several concentric circles are described and variously divided, according to the purposes which they are intended to serve. That towards the outer edge of the rim, is called the *calendar.* It is divided into 365 equal parts, representing the days in the year, classed under their respective months, and so arranged that the 20th of March exactly corresponds with the east point of the horizon. The next circle represents the *ecliptic* divided into signs and degrees, and so arranged that the first point in *Aries* corresponds with the 20th of March in the calendar, which brings each point of the ecliptic opposite to the day on which the sun is at that point.—The names and characters of the different signs are placed opposite the middle of each.

The next circle represents the horizon divided into 32 equal parts, representing the mariner's compass. And the innermost circle represents the horizon divided into quadrants, and these quadrants each into 90 degrees. Two of them are numbered from the east and two from the west towards the north and south.

The brazen or universal meridian is divided into degrees, reckoning in two of the quadrants from the equator towards the poles, and in the other two from the poles towards the equator, each quadrant being numbered from one to ninety. Two of these quadrants are used for ascertaining the latitudes of places on the globe, and the other two for raising either of the poles to a certain number of degrees.

The circle representing the *equator* is also divided into degrees in two directions, beginning at the first meridian, which, on British globes, is that of the royal observatory at Greenwich, near London, and extending to 180 degrees. This is used for ascertaining the longitudes of different places on the globe, intersecting the equator in every fifteenth degree.

The *ecliptic* is generally made to intersect the equator and the first meridian in the same point, the angle which it forms with the equator being 23 degrees and 28 minutes. It is divided into 12 signs, and each sign is subdivided into 30 degrees, and reckoned eastward from the first meridian. The characters of the signs are placed at the beginning or opposite the middle of each.

Parallel to the equator, and at the distance of 23 degrees, 28 minutes from it, are drawn two circles representing the *tropics* of *Cancer, Capricorn.* Parallel to the tropics, and at the distance of 23 degrees, 28 minutes from the poles, two other circles are drawn, representing the *arctic* and *antarctic circles.*

Parallels of latitude are also drawn intersecting the meridians in every tenth degree, on both sides of the equator.

Such is a general view of the artificial globe usually employed to represent the earth. It is called the *terrestrial globe,* to distinguish it from that used to represent the heavens, which is denominated the *celestial globe.*

The celestial globe, like the terrestrial, is suspended by the poles in a brazen meridian, and mounted in the same way in a horizon.

On its surface are described the equator, the eliptic, the tropics, the polar circles, the equinoctial and solstitial colures, circles of celestial longitnde, and parallels of celestial latitude. The brazen meridian and the ecliptic are divided in the same way as on the terrestrial; but the degrees of the equator are reckoned only in one direction, viz. towards the east. On the surface of the celestial globe the fixed stars are represented in their true relative situations, distinguished according to their apparent magnitudes, and arranged in constellations.

Besides the parts already described, there are the *horary* or *hour circle*, and the *quadrant of altitude*, that are appendages to both globes.

The *horary* is a small brass circle fixed with its centre on the north pole of the globe, and divided into 24 equal parts, representing the hours of the day. The divisions are reckoned from 1 to 12 along the first semicircle, and again from 1 to 12 on the other, commencing at the opposite point from the first. The circle is moveable by the hand, so that any hour may be brought to the brazen meridian; but when left to itself it turns with the globe.

The *quadrant of altitude* is a graduated slip of brass, so thin and flexible as to be easily applied to the surface of the globe. It is furnished at one end with a screw, by which it may be attached to any part of the brazen meridian. When this extremity is fixed on the zenith of the globe, the commencement of the graduation coincides with the horizon, and the part between that and the zenith is divided into 90 degrees. The graduation is also continued to the other extremity which is generally 18 or 20 degrees below the horizon.

The delineation of the different circles on the two globes, and of the different continents, oceans, islands, &c. on the terrestrial globe, and of the constellations and particular stars on the celestial, is performed in the following manner: strips of paper, called *gores*, are cut, having the form of the space that would be contained between two meridians, drawn on the globe, a few degrees apart. On these gores are delineated separate portions of the earth or heavens, according as they are intended for a terrestrial, or celestial globe. They are afterwards fixed in order on the surface of the globe prepared in the manner that has already been described, by paste or some other adhesive substance. When they are thus fixed, the whole is covered with a transparent varnish, to prevent it from being easily soiled or otherwise injured.

When perusing the terrestrial globe the eye of the observer is in its natural position; but when he is examining the celestial, he must conceive himself to be placed in the centre, and looking towards the concave surface.

SOLUTIONS OF PROBLEMS BY THE TERRESTRIAL GLOBE.

PROBLEM I.

To find the latitude and longitude of any place on the earth's surface.

Turn the globe until the given place is exactly under the graduated edge of the brazen meridian; then the degree of the meridian over the place will be its *latitude*, and the point of the equator intersected by the same edge of the meridian will be its *longitude.*

EXAMPLES.

What is the latitude, and the longitude of Philadelphia?

Ans. Lat. 40° N. Long. 75¼° W. nearly.

What is the latitude, and the longitude of Paris?

Ans. Lat. nearly 49° N. Long. 2° 20′ E.

What is the latitude, and the longitude of Lima, in Peru?

What is the latitude and the longitude of Canton, in China?

Note.—As the degrees on the meridian and equator are small, the latitudes and longitudes in these examples, are not generally given nearer than to quarters of a degree.

PROBLEM II.

The latitude and longitude of a place being given, to find the place on the globe.

Find the given longitude on the equator, and bring it to the graduated edge of the brazen meridian; then the place will be under the degree of the meridian denoting the latitude.

EXAMPLES.

The latitude of a certain place is 30° N. and its longitude 31¼° E.; what is the place?

Ans. Cairo.

The latitude of a place is 40° N. and its longitude 116½° E.; what is the place?

Ans. Pekin.

What island is situated in latitude 33¾° S. and longitude 79° W.?

Ans. Juan Fernandez.

What city is situated in latitude 23° N. and longitude 89¼, E.?

PROBLEM III.

To find the difference of latitude, and the difference of longitude between two places.

Find the latitudes of both places by Problem I. and take their difference, or sum, according as they are on the same side, or on *different* sides of the equator. The difference of longitude is found in the same way, by taking the difference, or sum of the longitudes, according as they are on the same side or on different sides of the first meridian.

EXAMPLES.

What is the difference of latitude, and the difference of longitude, between Philadelphia and Hamburg?

Ans. Diff. of Lat. 13½°; Diff. of Long. 85°.

What is the difference of latitude and the difference of longitude between Quebec and the Cape of Good Hope?

Ans. Diff. of Lat. 80¾°; Diff. of Long. 89½°.

What is the difference of latitude and the difference of longitude, between Petersburg, in Russia, and Valparaiso, in Chili?

What is the difference in latitude and the difference of longitude, between Dublin and New Orleans?

PROBLEM IV.

The hour being given at one place, to find the hour at any other place at the same time.

Bring the given place to the meridian and set the horary to the given hour; then turn the globe from east to west till the place at which the hour is required comes to the meridian, and the hours that pass under the meridian will be the difference in time between the two places. If the place at which the hour is required is east of that at which it is given, add this difference to the given time, but if the place is west, substract the difference from the given time.

EXAMPLES.

When it is six o'clock in the morning at Philadelphia, what is the time at London, and what at Vienna?

Ans. 11 o'clock at London; 5 minutes past 12 at Vienna.

When it is 10 o'clock in the evening at Petersburg in Russia, what time is it at Boston, and also at New Orleans?

Ans. 3 o'clock 15 minutes, afternoon, at Boston: 2 o'clock, afternoon, at New Orleans.

When it is six o'clock in the morning of the 21st of May, at Savannah, what time is it at Pekin, in China?

When it is four o'clock, P. M. at Philadelphia, what time is it at Berlin, on the 15th of January?

PROBLEM V.

To find the distance between two given places on the earth in statute miles.

Apply the graduated edge of the quadrant of altitude to the two places, and observe the number of degrees intercepted between them; these degrees multiplied by 69 will give the number of miles, *nearly*.

EXAMPLES.

What is the distance between London and Philadelphia? *Ans.* 3019 miles.

What is the distance between Philadelphia and Lima? *Ans.* 3590 miles.

What is the distance between Edinburgh and New Orleans?

What is the distance between Boston and Cape Horn?

PROBLEM VI.

To find the sun's Longitude and Declination on any given day in the year.

Find the given day in the calendar on the horizon, and opposite to it in the ecliptic will be the sun's *longitude*, commonly called the *sun's place*. Find this longitude in the ecliptic marked on the surface of the globe, and bring it to that part of the brazen meridian in which the degrees are numbered from the equator towards the pole; then the number of degrees intercepted between this point and the equator will be the sun's *declination*.

EXAMPLES.

What is the sun's longitude and declination on the 15th of April?

Ans. Long. 26°; Declin. 10° north.

Required the sun's place and declination on the following days:—January 21st, February 8th, June 15th, August 12th, December 1st.

PROBLEM VII.

To find those places in the torrid zone, to which the sun will be vertical, on any given day.

Find the sun's place in the ecliptic and bring it to the brazen meridian; mark the degree of the meridian over it; then all the places that pass under that degree while the globe is revolving, will have the sun vertical on that day.

EXAMPLES.

At what place is the sun vertical on the following days? viz. April 25th, June 6th, September 2nd, December 11th.

PROBLEM VIII.

The day and hour being given at any place, to find where the sun is then vertical.

Find the sun's declination, by Prob. VI. and mark it on the brazen meridian; bring the place and hour to the brazen meridian; then, if the hour is before noon, turn the globe westward; but if after noon, turn it eastward until the 12th hour of the horary comes to the brazen meridian, and the place where the sun is vertical will be under the degree denoting the sun's declination, marked on the meridian.

EXAMPLES.

When it is two o'clock in the morning on the 25th of April, at Boston, where is the sun vertical? *Ans.* At Madras.

When it is twenty minutes past five P. M. on the nineteenth of May, at Philadelphia, where is the sun vertical?

Ans. At Owhyhee.

When it is a quarter past six o'clock in the morning, at London, on the tenth of June, where is the sun vertical?

PROBLEM IX.

To find the sun's meridian altitude at any place, on any given day.

If the given place is north of the equator, elevate the north pole of the globe as many degrees as the place is north of the equator; but if the place be in south latitude, elevate the south pole as many degrees as are denoted by the latitude of the place; then find the sun's place for the given day and bring it to the brazen meridian; the nnmber of degrees of the meridian, intercepted between the sun's place and the horizon, will give the sun's meridian altitude.

EXAMPLES.

What is the sun's meridian altitude at

Philadelphia on the twenty-first of June?
Ans. 73° 28′.

What is the sun's meridian altitude at Boston on the twentieth of March?
Ans. 48° 28′.

What is the sun's meridian altitude at Petersburg, in Russia, on the twenty-first of December?

What is the sun's meridian altitude at Manilla, on the tenth of April?

PROBLEM X.

The day and hour being given at any place, to find all those places where the sun is rising, those where the sun is setting, and those that have noon.

Find the sun's declination for the given time, and elevate the north or south pole, according as the declination is north or south, until the number of degrees above the horizon is equal to the declination. Bring the given place and hour to the meridian, and turn the globe towards the west or east, according as the hour is before or after noon, until 12 of the hour circle be under the meridian. To all the places in the western side of the horizon the sun is rising; to those in the eastern side he is setting; and to those under the brazen meridian it is noon.

EXAMPLES.

On the 20th of March, at 1 o'clock P. M.

at Philadelphia, where is the sun rising? where is he setting? and where is it noon?

Ans. The sun will be rising a little west of Bhering's strait and the Friendly islands; setting at London, Havre de Grace, Alicant, and the Gold Coast of Africa: and it will be noon at New Orleans, the Bay of Honduras, and the Gallipagos Islands.

When it is 11 o'clock A. M. at Philadelphia, on the 25th of April, where is the sun rising, setting, &c.?

PROBLEM XI.

To find the time of the sun's rising or setting, on any day, at any place whose latitude is not greater than 66° 32′.

Elevate the pole according to the latitude of the place, as in Prob. IX. and bring the sun's place in the ecliptic, as well as the 12th hour of the horary to the meridian. Then turn the globe eastward until the sun's place comes to the horizon, and the hour under the meridian will be the time of sun-rising. In like manner, by turning the globe westward until the sun's place is in the horizon, we have the hour of sun-setting under the meridian.

EXAMPLES.

At what time does the sun rise and set at

Charleston, South Carolina, on the 20th of June?

Ans. Rises at 5 o'clock, Sets at 7 o'clock.

At what time does the sun rise and set at Petersburg, Russia, on the 21st of December?

Ans. Rises ¼ past 9 o'clock, Sets ¼ before 3 o'clock.

At what time does the sun rise and set at Tornea, at the head of the Gulf of Bothnia, on the 21st of June?

At what time does the sun rise and set at Philadelphia, on the 20th of April?

PROBLEM XII.

To find the length of any day or night at any place, whose latitude does not exceed 66° 32'.

Find the hour of sun rising and setting by Prob. XI. Double the time of sun-rising, and it will give the length of the night; double the time of sun-setting, and it will give the length of the day.

EXAMPLES.

What is the length of the 21st day of June, and also of the night succeeding it, at Edinburg?

Ans. Length of the day, 17 ½ hours; length of the night, 6 ½ hours.

What is the length of the day on the 21st of December, at Stockholm?

Ans. 5½ hours.

What is the length of the night, on the 25th of May, at Skalholt, in Iceland?

What is the length of the day at Boston, on the first of April?

PROBLEM XIII.

To find the length of the longest day in the north frigid zone.[*]

Elevate the north pole equal to the latitude of the given place; then, in turning the globe, observe what points of the ecliptic cut the north point of the horizon. Find those points in the ecliptic, delineated on the horizon, and opposite to them in the calendar, will be the days on which the longest day at the given place begins and ends. The one preceding the 21st of June will denote the beginning, and that following it, the end.

EXAMPLES.

What is the length of the longest day at the North Cape, in the island of Maggeroe, in latitude 71° 30′ north?

Ans. It begins on the 14th of May, and ends on the 30th of July. It is therefore seventy-seven days long.

What is the length of the longest day at the northern extremity of Nova Zembla, in latitude 77° north?

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[*] When we speak of the longest day in either of the frigid zones, we mean the time during which the sun is continually above the horizon. At the poles it is one half the year.

PROBLEM XIV.

To find the length of the longest night at any place in the north frigid zone.

Elevate the north pole, as in Prob. XIII. and turning the globe, observe what points of the ecliptic cut the south point of the horizon. Then find the corresponding points in the ecliptic on the horizon, and the days in the calendar opposite to these points will be those on which the longest night begins and ends. That preceding the 21st of December will be the beginning, and that following it, the end.

EXAMPLES.

What is the length of the longest night at the North Cape, in the Island of Maggeroe, in lat. 71° 30′ north?

Ans. The longest night commences on the 16th of November, and ends on the 27th of January; it is therefore 73 days long.

What is the length of the longest night at the northern extremity of Nova Zembla, in lat, 77° north?

What is the length of the longest night in the island of Spitsbergen, in lat. 80° north?

PROBLEM XV.

To find the beginning, end, and duration of twilight, at any place, on any given day.

Elevate the north or south pole according to the latitude of the place, as in Prob. IX. find the sun's place in the ecliptic, bring it and the 12th hour of the horary to the brass meridian, and screw the quadrant of altitude to the brass meridian at the given latitude; turn the globe westward until the sun's place comes to the horizon, and the index will show the time of sun-setting, or beginning of twilight: continue the motion westward until the sun's place coincides with 18° below the horizon, on the quadrant of altitude; the horary will then show the end of twilight; substract the time of sun-setting from this, and we have the duration of twilight. Morning twilight may be found nearly in the same manner as the evening, by turning the globe eastward; its length is the same on the same day.

EXAMPLES.

Required the beginning, end, and duration of evening twilight at London, on the 19th of April.

Ans. It begins two minutes past seven; ends nineteen minutes past nine; duration two hours and seventeen minutes.

Required the beginning, end, and duration of evening twilight at Edinburgh on the 21st of March.

Required the beginning, end, and duratio of morning twilight at Cape Horn, on the 1st of April.

As twilight does not end in the evening until the sun has descended 18° below the horizon, it follows that at all places whose north latitudes are greater than 48½°, there will be one or more nights about the 21st of June on which twilight will continue the whole night, although those places may not be in the north frigid zone.

PROBLEM XVI.

Any place whose latitude is greater than 48° 30′ *being given, to find the beginning, end, and duration of constant twilight, agreeable to the preceding observation.*

Find the latitude of the given place and add 18° to that latitude; count the number of degrees corresponding to this sum, on that part of the brass meridian which is numbered from the pole towards the equator, and mark where the reckoning ends; make the globe revolve upon its axis and observe the points of the ecliptic that pass under the mark on the meridian; find the same degrees in the ecliptic on the horizon, and the days corresponding to them will be those on which constant twilight begins and ends.

EXAMPLES.

When does constant twilight begin at

London, and how long does it continue?

Ans. It begins the 22nd of May, and ends the 21st of July.

When does constant twilight begin, and how long does it continue, in the Shetland Islands?

What is the duration of constant twilight at Edinburgh?

SOLUTIONS OF PROBLEMS BY THE CELESTIAL GLOBE.

PROBLEM I.

To find the right ascension and declination of the sun, or of a star.

Bring the sun's place, or the star to that part of the brass meridian which is numbered from the equator towards the poles; the degree on the brass meridian will be the declination; and the degree of the equator under the graduated edge of the meridian will be the right ascension.

EXAMPLES.

Required the right ascension and declination of the star *Dubhe* in Ursa Major.

Ans. Right ascension, 162° 49′, Declination, 62° 48′ north.

What is the right ascension and declination of the sun on the second of June?

Ans. Right ascension, 71°; Declination, 22° N.

What is the right ascension and declination of *Sirius* in Canis Major?

Required the right ascension and declination of *Aldebaran*, in Taurus.

PROBLEM II.

To find the latitude and longitude of a given star.

Place the upper extremity of the quadrant of altitude on the north or south pole of the ecliptic, according as the given star is north or south of the ecliptic, and let its graduated edge fall upon the star; then the degree of the ecliptic intersected by the quadrant, will be the longitude of the star, and the degree of the quadrant over the star will be its latitude.

EXAMPLES.

Required the latitude and longitude of *Aldebaran*, in Taurus.

Ans. Latitude 5° 28′ south, Longitude 2 signs 6° 53′.

Required the latitude and longitude of *Antares*, in Scorpio.

Ans. Latitude 4½° south, longitude 8 signs 6½°.

Required the latitude and longitude of *Alpheca*, in Corona Borealis.

What is the longitude and latitude of *Capella*, in Auriga?

PROBLEM III.

To dispose the globe so as to exhibit the actual situations of the different stars at any time and place.

Elevate the pole according to the latitude of the place, set the globe due north and south, and bring the sun's place and the 12th hour of the horary to the graduated edge of the meridian. Turn the globe towards the east or west, according as the time is before or after noon, until the given hour on the horary comes to the meridian, and the globe will then exhibit the actual situation of the different stars at that time and place.

PROBLEM IV.

To find what stars are rising, setting or on the meridian, at any given time and place.

Dispose the globe as in Prob. III.; then the stars corresponding with the eastern edge of the horizon are rising, those corresponding with the western edge are setting, and those under the graduated edge of the brass meridian, are on the meridian of the given place.

EXAMPLES.

On the 9th of February, at nine o'clock in the evening, at London, what stars are rising, what stars are setting, and what stars are on the meridian?

> *Ans. Alpheca*, in Corona Borealis, is ri-rising; *Arcturus* and *Mirach*, in the Bootes, just above the horizon; *Sirius* on the meridian; and the constellations *Orion* and *Taurus* are a little west of the meridian; and *Markab* in Pegasus, just below the western part of the horizon.

On the 2nd of December, when it is six o'clock in the evening at Philadelphia, what stars are rising, setting, and on the meridian?

On the first of October, when it is eight o'clock in the evening, at Quebec, what stars are rising, setting, and on the meridian?

PROBLEM V.

To find the time when any star will rise, set, or be on the meridian of any place, on a given day.

Elevate the pole according to the latitude of the given place, and bring the 12th hour of horary to the meridian. Then bring the star successively to the eastern edge of the horizon, to the meridian, and to the western edge of the horizon, and the times of rising, being on the meridian, and setting, will be respectively shown by the index of the horary.

EXAMPLES.

At what times will *Arcturus* rise, come to the meridian, and set, at London, on the 7th of September?

Ans. It will rise at 7 in the morning, come to the meridian at 3 in the afternoon, and set at 11 at night.

At what times will *Sirius* rise, come to the meridian, and set, at Philadelphia, on the 7th of November?

At what time will *Lyra* rise, come to the meridian, and set, at Philadelphia, on the 10th of August?

PROBLEM VI.

To find the angular distances between the different stars, in degrees.

Lay the quadrant of altitude over any two stars, so that the division marked o, may be on one of them; the degree of the quadrant over the other star will be the angular distance between them.

EXAMPLES.

What is the angular distance between *Lyra* and *Atthir*, in Aquila?

Ans. 34 degrees.

What is the angular distance between *Sirius* and *Aldebaran*?

What is the angular distance between *Dubhe* in *Ursa* Major, and Arcturus in Bootes?

QUESTIONS.

NOTE.—The figures before each question refer to the article in which the answer to the question will be found. It would be an advantage to the student, in answering a question, to recite in substance all that is contained in the article referred to, excepting where more questions than one refer to the same article.

1. What is Philosophy?
2. How is Philosophy divided?
3. Of what does Moral Philosophy treat?
4. What is the object of Natural Philosophy?
5. How many axioms are there in Natural Philosophy?
   What is the first?
   What is the second?
   What is the third?
   Observation. What appearances are contrary to this?
   What is the fourth axiom?

OF MATTER AND ITS PROPERTIES.

6. How is matter defined?
7. What are the properties of matter?
8. What is solidity?
   Illustration 1. Illustrate the definition of solidity.
   2. What have this property beside wood and metal?
   Ex. 1. and 2. What experiment shows that water and air have this property?
   Corollary. What inference is deduced from this?
9. What is meant by divisibility?
9. Has this any limit?
   Illustration 1. and 2. How is it shown that there is no limit to the divisibility of matter?

Ex. 1. Mention the experiment of melting a grain of gold, with a pound of silver.

2. What part of a grain of gold, when beaten by the gold beaters, may be seen by the naked eye?

3 and 4. What is said of animalculæ, and of light?

Corollary. What is the inference from all these?

10. What is mobility?

Illustration. Is all matter capable of being moved?

11. What is inertness?

Illustration 1. How is this illustrated?

Illustration 2. What causes moving bodies to come to a state of rest?

Ex. 1. Mention the experiment with a marble.

Ex. 2. Mention the experiment with a cannon ball.

Ex. 3, *and* 4. Illustrate the inertness of matter by the motion of a boat and of horses.

OF ATTRACTION AND REPULSION.

12, What is meant by attraction?

13. How many kinds of attraction are there?

14. What is the attraction of cohesion?

15. When does the attraction of cohesion take place?

Illustration 1. How does heat affect the attraction of Cohesion?

2. Illustrate this principle by ice.

3. On what principle are bodies melted?

4. On what principle are bodies broken?

4. Upon what principle may they be mended?

Ex. 1. Describe the experiment of the leaden bullets.

2. Explain the principle of welding.

3. Explain the principle of soldering and glueing.

4. Describe the experiment with two globules of quicksilver.

16. What is capillary attraction?

Ex. 1. Describe the experiment with a small tube.

2. Describe the experiment with two pieces of glass.

2. What is the name of the curve formed?

Why does the water rise higher on one side than the other?

3. On what principle do sugar, sponge, &c. draw up water?

17. What effect have different degrees of cohesion on bodies?

18. What is repulsion?

19. Where does the repulsive force begin?

Illustration. Is the repulsive force of the particles of fluids or solids the greatest?

Ex. 1. Describe the experiment with a sewing needle.

2 and 3. Describe the experiment with drops of water and ball of light wood.

Observation. Do these experiments properly illustrate attraction or repulsion?

20. What is the attraction of gravitation?

21. What effect has gravitation on a stone and the heavenly bodies!

Observation. Does gravitation extend beyond the earth?

22. Towards what do the planets gravitate?

23. Towards what do all terrestrial bodies tend?

Observation. What appear to be exceptions to this?

24. In what places is the force of gravity equal?

25. Is the force of gravity greatest at the equator or poles, and why?

26. Where is the force of gravity the greatest?

27. How does it decrease upwards and downwards?

Illustration. Illustrate this.

Observation 1. Is it known what the *cause* of gravitation is?

Observation 2. Upon what principle do some rivers run up hill?

2. How much further is the mouth of the Mississippi from the centre of the earth than its source?

OF MOTION.

28. How is motion defined?
29. Is motion important?
30. What is the first law of motion?
30. What is the second?
30. What is the third?

Observatian 1 *and* 2. *Ex.* Illustrate this.

31. With how many kinds of motion are we concerned, and what are they?

Illustration. Illustrate them.

Ex. 1. What experiment shows particles in water?

2. What experiment shows the particles floating in air?

32. How many things are to be noticed with regard to motion, and what are they?
33. What is the consequence of the inertness of bodies?
34. What are the causes of motion called, and what are they?
35. How is the velocity of motion estimated?
36. How is the degree of velocity ascertained?

Ex. 1 and 2. Give the examples.

37. How is the space run over measured?

Illustration. Illustrate this.

38. Towards what does a body in motion tend?
39. When is motion in a strait line?
40. When in a curve?
41. How does a body move when acted upon by only one force or by several forces in the same direction?
42. What is meant by the composition and resolution of motion?

Illustration. Illustrate this by the figure.

Ex. 1. What instances are there in nature of compound motion?

2. Describe the motion of a body let fall from the top of a mast.

Observation 1. What curve does a body describe when thrown obliquely into the air?

1. At what elevation will it go the furthest?
 2. How is a cannon ball acted upon?
43. What is accelerated motion?
44. What is uniformly accelerated motion?
 Example. Give an instance.
45. When is motion said to be retarded?
46. What are the velocities of falling bodies in proportion to?
47. How do the velocities increase in each instant?
 Il. Illustrate this.
 Ob. What is remarkable in these odd numbers?
 Cor. What is the inference?
 Ex. Give an example.
48. How does a falling body move?
 Ob. 1. How is the whole space fallen through in any number of seconds ascertained?
 2, How is the velocity acquired ascertained?
 3. How will we find the time required to fall through any given space?
 4. With what force will a cannon ball return to the earth?
49 and 50. What is meant by the momentum of a body?
 Il. If equal bodies have different volocities, in what proportion are their momenta?
 Ex. 1 and 2. Give the experiments.
 Cor. What are the momenta of bodies in proportion to?

CENTRAL FORCES, AND THE CENTRE OF GRAVITY.

51. What kind of motion is produced by only one force?
 Cor. What is the inference from this?
 Ex. Describe the experiment with a sling.
52. What is meant by centrifugal force?
53. What is the centripetal force?
54. What are central forces?
54. What relation is there between these forces when a body moves in an orbit?

55. What is meant by the centre of gravity?

Ob. 1. Where is the centre of gravity of a regular body?

1. Where is the centre of gravity in a parrallelogram?

2. How do we find the centre of gravity of a triangle?

3. How may we find the centre of gravity of any body mechanically?

56. When will a body rest in any position?

57. Where is the whole weight of a body centred!

58. Where is the centre of gravity of two or more bodies?

59. What is meant by the line of direction, and why is it so called?

60. When will a body stand, and when fall?

Il. Explain this by a figure.

Cor. What inference is deduced from this?

61. When does a body stand most firmly?

62. When is a body easily overthrown?

Cor. What is the inference?

63. and *Il.* When will a body slide, and when roll down an inclined plane?

Ex. 1. When do persons stand and fall?

2. How are rope dancers enabled to perform their feats?

3. How do we frequntly apply this principle?

OF THE MECHANICAL POWERS.

64. What are the mechanical powers?
Why are they called so?

65. Is every machine made up of these?

66. What things are to be considered in treating of mechanical engines?

67. How many mechanical powers are there, and what are they?

68. In what state is the power of a machine calculated?

Obs. What is to be observed in the use of all mechanical powers?

69. What is a lever?

70. *How many kinds of levers are there, and how are they distinguished?*

OF THE LEVER.

71. How is the advantage in all levers estimated?
72. Describe a lever of the first kind.
  Il. Explain this by a figure.
  Ex. 1. 2. and 3. Mention some instances of levers of the first kind.
  4. What instruments act on the principle of the first kind of lever?
73. For what is a lever of the first kind used?
  Il. Illustrate this by a figure.
  Ex. 1. Give the experiment of carrying a weight on a pole.
  2. Give the experiment with two horses.
  3. What may be referred to this kind of lever?
74. Describe a lever of the third kind.
75. Is the power or the weight the greater in this lever?
  Il. Explain this by a figure.
  Ex. 1. Describe the experiment with a ladder.
  2. What kinds of levers are the wheels in clock and watch work, and why?
  3. What kind are natural levers?
  3. Explain this by a figure.
  Cor. How is the loss of power compensated?
76. What is a hammer lever?
  Ex. 1. Describe the experiment with a hammer.
  Cor. What is the advantage gained always in proportion to?

OF THE WHEEL AND AXIS.

77. Describe the wheel and axis.
78. How do we estimate the advantage gained?
  Il. Explain this by a figure.
  Ex. 1. What are referred to the wheel and axis?
  2. When the axis is turned by a winch, how is the advantage estimated?
  3. What is a capstan?

OF THE PULLEY.

79. What is a pulley?

80. What is a sheeve, and how fixed?
81. What kinds of pullies are there?
82. Of what use is the fixed pulley?
83. Describe the moveable pulley, and tell its advantage.
Il. What is the reason of this?
84. When there are two pullies in the lower block, how do we estimate the advantage?
Il. Explain this.
85. How is the advantage estimated generally?
86. What is a tackle?

OF THE INCLINED PLANE.

87. What is the inclined plane?
88. How is it frequently made?
89. With what force does a body descend on an inclined plane?
Il. 1. 2. and 3. Illustrate this.
90. How is the advantage gained by the inclined plane estimated?
What is the advantage when the plane is ten times as long as it is high?
91. What instruments may be referred to the inclined plane?

OF THE WEDGE.

92. What is the wedge?
93. How is the advantage gained by the wedge estimated?
94. What is the advantage when the wood cleaves before the wedge?
95. What is the wedge used for?
96. What instruments are referred to the principle of the wedge?

OF THE SCREW.

97. How is the screw used?
98. How may the screw bo conceived to be made?
99. How is the advantage gained by the screw ascertained?

Il. Illustrate this by the figure.
Ex. Give the example.
Cor. What is the inference?
100. In what different ways may a screw be moved?
101. What instruments act on the principle of the screw?
102. What is an endless screw?
103. What allowance is to be made for friction?
Ex. Give the example.
Ob. Which has the least friction, and which most?
Ob. How may friction be diminished?
104. How do we explain the maxim, that what is gained in power is lost in time?
Ex. Illustrate this.
105. Of what advantage, then, are the mechanical powers?
106. What is the other advantage mentioned?

OF THE MOVING POWERS.

107. What are the principal moving powers?
108. What power is most easily applied?
109. Why is the weight chiefly used for slow movements?
110. In what respect is the spring like the weight?
111. In what does it differ?
Ex. How is this defect rectified in watches?
112. To what is the steam of boiling water applied?
113. To what are running water and wind applied?
114. Why is running water preferable to wind as a mover of machines?
115. What is the strength of a man compared with that of a horse?

OF PENDULUMS.

116. What is a pendulum?
Ob. How do pendulums move?
117. What is meant by a vibration?
118. How are vibrations performed?
119. Are the vibrations slower in long or short pendulums?
120. What is the length of a pendulum that vibrates seconds?

121. Is a pendulum that vibrates seconds longer at the poles or equator?
Il. What is the reason of this?
122. How long is a pendulum that vibrates half seconds?
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125. Do clocks go faster in cold or warm weather, and why?

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126. What is a fluid?
127. How are fluids divided?
Ob. What is said of the compressibility of water, &c.?
2. Of what nature are the particles of fluids, and what is the consequence of this?
2. Is the bulk of water increased by dissolving salt, &c.?
3. Is a given bulk of salt or fresh water the heavier?
128. Of what does the science of hydrostatics treat?
129. To what laws are fluids subject?
130. How do fluids differ from solids?
131. How do fluids press?
Ex. How is the upward pressure shown?
132. When will a fluid remain at rest?
Ex. Describe the experiment with pipes.
133. How is the pressure of a fluid estimated?
Ex. Describe the experiment with a bladder, to show the different pressure at different depths.
2. Describe the experiment with an empty bottle.
134. What pressure does the horizontal bottom of a vessel sustain?
Ex. 1 and 2. Does the shape of the vessel make any difference?
135. How is the pressure upon any given part of the bottom or sides estimated?
Cor. What is the inference?
136. What is the hydrostatical paradox?
Ex. Explain this by the figure.

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135. How is the pressure upon any given part of the bottom or sides estimated?
  Cor. What is the inference?
136. What is the hydrostatical paradox?
  Ex. Explain this by the figure.

137. By what instrument is the upward pressure of fluids shown?

Il. How is the hydrostatical bellows made?

SPECIFIC GRAVITIES.

138. What is meant by the specific gravities of bodies?

139. With what is the weight of bodies compared?

140. When will a body sink in a fluid?

141. How much will a body lose of its weight when suspended in a fluid?

Il. What does a cubic foot of water weigh?

How many ounces of their weight will 16 cubic feet of metal lose when suspended in water?

142. When do bodies lose equal weights and when unequal?

143. How far will a body that is lighter than a fluid sink in that fluid?

144. Will a body sink deeper in a light or heavy fluid and why?

145. When will a body remain at rest in a fluid?

146. When will a body sink in a fluid?

147. Describe the hydrostatic balance.

Il. Relate the manner of finding the specific gravity.

148. How are the specific gravities of all bodies found?

Ex. If a body weigh 28 oz. in air and 26 in water, what is its specific gravity?

149. What is the hydrometer?

HYDRAULICS.

150 What does the science of hydraulics teach?

151. What machines depend on hydraulics?

152. Upon what principle are fluids conveyed over hills?

152. How high can they be carried?

153. Upon what principle are fountains formed?

154. Of what does the common pump consist?

Il. Explain its structure by the figure

155. Of what does the forcing pump consist?

Il. Explain its structure by the figure.

156. What raises the water in the common pump?
156. How high can it be raised by the air?
157. How high can water be raised by the forcing pump?
158. For what is the air vessel added?
159. How may a constant stream be produced?
160. What is a syphon?
  Il. 1. How is the syphon used?
  2 and 3. What is necessary in using the syphon?
161. Of what does the science of pneumatics treat?
162. Where does the air exist?
163. What is the atmosphere?
  Ob. Of what is the air composed and in what proportion?
  Ob. To what is the oxygen necessary?
164. Why is the air not visible?
  Ex. 1 and 2. How is the existence of the air ascertained?
  3. Show its existence with a glass vessel.
165. How does the air press?
  Ex. 1. Is the pressure greater at the top or bottom of a mountain and why?
  2. Describe the experiment with a wine glass to show the upward pressure of the air?
166. Can the air be compressed?
  Ex. 1. Describe the experiment with a glass tube.
  2. Describe the experiment with a tumbler and cork.
  3. Describe the diving bell.
167. Of what nature is the air?
168. What is the force of its spring equal to?
  Ex. 1. Describe the experiment with a bladder to prove the elasticity of air.
  3. Describe the experiment with bellows to prove the solidity of air.
168. What is the consequence of removing the pressure from air?
169. What is wind?
  Ob. 1. What are the most general causes of wind and in what way?
  2. Why does the wind always come from a thunder cloud when it gets near?
  3. What effect have the sun and moon?
  4. What is the trade wind?

1. At what elevation will it go the furthest?

2. How is a cannon ball acted upon?

43. What is accelerated motion?

44. What is uniformly accelerated motion?

Example. Give an instance.

45. When is motion said to be retarded?

46. What are the velocities of falling bodies in proportion to?

47. How do the velocities increase in each instant?

Il. Illustrate this.

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Cor. What is the inference?

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2, How is the velocity acquired ascertained?

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Il. If equal bodies have different volocities, in what proportion are their momenta?

Ex. 1 and 2. Give the experiments.

Cor. What are the momenta of bodies in proportion to?

CENTRAL FORCES, AND THE CENTRE OF GRAVITY.

51. What kind of motion is produced by only one force?

Cor. What is the inference from this?

Ex. Describe the experiment with a sling.

52. What is meant by centrifugal force?

53. What is the centripetal force?

54. What are central forces?

54. What relation is there between these forces when body moves in an orbit?

6. Describe the guinea and feather experiment.
7. Describe the experiment with a cup of porous wood.
8. Describe the experiment with the brass hemispheres.
9. Describe the experiment to break a phial by the pressure of air.
10. Show the elasticity of air by a bladder.
11. Tell how to break a phial by the expansion of air.
12. How may a shrivelled apple be made smooth?
13. Describe the experiment with an egg.
14. How may beer be made to appear to boil without heat?
15. Why does smoke ascend?
16. and *Cor.* Can sound be heard without air?
17. To what else is air necessary?
18. Describe the artificial fountain.
19. Is sound louder in condensed or common air?
20. In what way may a square phial be broken besides those mentioned?

OF ACOUSTICS.

182. What is acoustics?
182. What are diacoustics and catacoustics?
183. In what state is a sonorous body while sounding?
Ob. What effect do sounding bodies produce on the air?
184. What are the principal causes of the variety of sounds?
185. Upon what does the continuance of the vibrations of a sounding body depend?
Ex. Explain this by a figure
186. To what are the vibrations of a string communicated?
Ex. Explain this by a figure.
187. How is sound propagated?
188. How fast does sound travel?
189. Is there any difference in the velocity of high and low sounds?
190. Is the velocity of sound effected by winds?
191. To what has the knowledge of the velocity of sound been applied?
Ex. How far will sound fly in thirty seconds?

192. How are sounds conveyed?
 Ex. 1. Give an experiment to show that wood will conduct sounds.
 2. Describe the experiment to show woollen, &c. will conduct sound.
 3. Describe the experiment with a watch.
 4. How do persons discover the approach of horses, &c?
 5. How far have the human voice and cannon been heard?

193. What is echo?
 Ex. 1. Describe the experiment?
 2. To what purpose can the return of sound be applied?
 Ex. Give the example.

194. Upon what principle are whispering galleries constructed?

195. What effect have tubes upon sounds?

OPTICS.

196. Of what does light consist?

196. What is meant by a ray of light?
 Ob. What is meant by a luminous body?
 Ex. How much space will the light of a candle fill?

197. How fast does light travel?

198. How is it shown that the particles of light are small?
 Ex. 1. Describe the experiment with a row of candles.
 2. Describe the experiment with black paper.

199. How do we obtain the idea of light?

200. How do we obtain the idea of bodies?
 Ex. Give the experiment.

201. What is said of the continuance of the impression made by light upon the eye?
 Il. 1. Illustrate this by a live coal.
 2. What effect has looking at the sun, &c.?
 2. How far may the particles of light be apart and preserve uninterrupted vision?

202. Does every point of a body reflect light?
 Cor. What is the inference?

203. How do the rays of light move?
 Ex. 1 and 2. What is the proof of this?

204. What is meant by a pencil of rays?

205. What is a medium?

206. What is an opaque body?

80. What is a sheeve, and how fixed?
81. What kinds of pullies are there?
82. Of what use is the fixed pulley?
83. Describe the moveable pulley, and tell its advantage.
   Il. What is the reason of this?
84. When there are two pullies in the lower block, how do we estimate the advantage?
   Il. Explain this.
85. How is the advantage estimated generally?
86. What is a tackle?

OF THE INCLINED PLANE.

87. What is the inclined plane?
88. How is it frequently made?
89. With what force does a body descend on an inclined plane?
   Il. 1. 2. and 3. Illustrate this.
90. How is the advantage gained by the inclined plane estimated?
   What is the advantage when the plane is ten times as long as it is high?
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OF THE WEDGE.

92. What is the wedge?
93. How is the advantage gained by the wedge estimated?
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OF THE SCREW.

97. How is the screw used?
98. How may the screw be conceived to be made?
99. How is the advantage gained by the screw ascertained?

223. What is a plano-convex lens?
224. What is a plano-concave lens?
225. What is a double convex lens?
226. What is a double concave lens?
227. What is a meniscus?
228. What is the axis of a lens?
22.). What is meant by the principal focus of a lens?
Ex. Explain this by a figure.
230. What is meant by the focal distance?
231. To what is the focal distance of a plano-convex lens equal?
232. To what is the focal distance of a double convex lens equal?
233. Where are the rays of the sun collected?
234. How is the heat at the focus estimated?
Il. Give the illustration.
Cor. 1. How are common burning glasses constructed?
2. How does a globular decanter of water act?
Ob. 1. What sized lens will melt gold?
2. What coloured bodies are most easily set on fire?
235. Where must a lens be placed that the rays may go out parallel?
236. Where must a candle by placed for the rays to become parallel upon going out of the lens?
237. Where must the candle be placed for the rays to diverge?
238. Where must the candle be placed for the rays to converge?
238. Do the rays from a near or distant object meet sooner?
239. What is formed where the rays meet?
Ex. 1. How may the inverted image of a candle be seen?
2. What effect will covering a part of the lens have?
3. Explain by a figure how the image becomes inverted.
What will be produced by bringing the object nearer the glass?
240. What regulates the size of the picture?
240. When is the picture equal to the object, when less, and when greater?
Ob. 1. How are caustic curves shown?
2. What is said of these curves?
2. What should lenses be?

121. Is a pendulum that vibrates seconds longer at the poles or equator?
   Il. What is the reason of this?
122. How long is a pendulum that vibrates half seconds?
123. How long is a pendulum that vibrates once in two seconds?
124. How are the lengths of pendulums estimated generally?
125. Do clocks go faster in cold or warm weather, and why?

HYDROSTATICS.

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127. How are fluids divided?
   Ob. What is said of the compressibility of water, &c.?
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133. How is the pressure of a fluid estimated?
   Ex. Describe the experiment with a bladder, to show the different pressure at different depths.
   2. Describe the experiment with an empty bottle.
134. What pressure does the horizontal bottom of a vessel sustain?
   Ex. 1 and 2. Does the shape of the vessel make any difference?
135. How is the pressure upon any given part of the bottom or sides estimated?
   Cor. What is the inference?
136. What is the hydrostatical paradox?
   Ex. Explain this by the figure.

Ob. What is said of light's retracing the same lines ?

259. Where will the image of a remote terrestrial object be found ?

259. In what position will it be ?

261. When is the image larger than the object ?

262. When is the image less than the object ?
Where is the image in each of these instances ?
Ex. Describe the experiment with a concave mirror.

263. What is said of caustics by reflection ?
Ob. 1. Where may these curves be seen ?
2. What should mirrors be ?

264. What is said of images from convex reflectors ?

265. What is meant by virtual focus ?

266. Where is the virtual focus of rays that come from near objects ?

267. Where is the reflection supposed to take place ?
Ex. 1. Describe the experiment of the endless gallery.
2. Describe the other experiment.
Ob. If the surfaces make an angle of 30°, how many objects will there appear to be ?

OF THE DIFFERENT REFRANGIBILITY OF THE RAYS OF LIGHT.

268. Is light a simple body ?

268. Of how many species does it consist ?
Ob. 1. When is light separated into its primitive colours ?
1. What was thought of this dispersion ?
1. How has the defect been remedied ?
1. What are such lenses called ?
2. How is the dispersion increased ?

269. How are the different coloured rays examined ?
Il. Explain this by a figure.
Il. Enumerate the different rays in order, beginning with the one the least turned out of its course.

270. What proportion of the spectrum is occupied by each particular ray ?
Ob. Where is the greatest power of illumination ?

271. What effect is produced by mixing the seven colours ?

Ex. 1. Describe the experiment with a circular board.
2. Describe the experiment with a concave mirror.
272. To what colours are the seven reducible.
Ob. What is said of a colour being formed from two others?
273. What is the most remarkable instance of the separation of the rays of light?
274. How is the rainbow formed?
275. and 276. Where are the colours of the rainbow often seen?
277. When is the arc largest?
278. Is there ever more than one bow seen?
278. Which bow has the brightest colours?
Ob. 1. What is said of the order of the colours in the two bows?
2. How many refractions and reflections does the light undergo in each bow?
2. When do they become invisible?
279. What is said of lunar rainbows?
280. What are halos or coronas?
Ob. How are they formed?
281. What is meant by a primary colour?
281. What is meant by a secondary colour?
Ob. What is the appearance of things when viewed in any particular coloured ray?
282. From what do the colours of bodies arise?
Il. Illustrate this.

OF THE EYE AND VISION.

283. Of what is the eye composed?
284. What are the names of the three coats?
285. What are the names of the three humours?
Il. 1. Explain the structure of the eye by the figure.
What is the iris, and how found?
2. What is the pupil?
2. Is the pupil always of one size?
2. How is it contracted and enlarged?
3. What benefits result from this construction of the pupil?
4. Why can a person see better after being out some time in the evening?

Il. Illustrate this by the figure.
Ex. Give the example.
Cor. What is the inference?
100. In what different ways may a screw be moved?
101. What instruments act on the principle of the screw?
102. What is an endless screw?
103. What allowance is to be made for friction?
Ex. Give the example.
Ob. Which has the least friction, and which most?
Ob. How may friction be diminished?
104. How do we explain the maxim, that what is gained in power is lost in time?
Ex. Illustrate this.
105. Of what advantage, then, are the mechanical powers?
106. What is the other advantage mentioned?

OF THE MOVING POWERS.

107. What are the principal moving powers?
108. What power is most easily applied?
109. Why is the weight chiefly used for slow movements?
110. In what respect is the spring like the weight?
111. In what does it differ?
Ex. How is this defect rectified in watches?
112. To what is the steam of boiling water applied?
113. To what are running water and wind applied?
114. Why is running water preferable to wind as a mover of machines?
115. What is the strength of a man compared with that of a horse?

OF PENDULUMS.

116. What is a pendulum?
Ob. How do pendulums move?
117. What is meant by a vibration?
118. How are vibrations performed?
119. Are the vibrations slower in long or short pendulums?
120. What is the length of a pendulum that vibrates seconds?

304. Upon what does the solar microscope depend?
305. Of what is it composed?
306. Describe its action.
307. How is the magnifying power estimated?
  Ex. Give an example.
308. What are telescopes, and how many kinds are there?
309. Of what does the refracting telescope consist?
310. In what position are the images?
311. How is its magnifying power estimated?
  Ex. Mention an example.
312. How may this telescope be constructed to show objects in their natural position?
  Ob. 1. What effect is produced by looking in the large end of a telescope?
  2. Who constructed the largest telescope ever made?
  2. What is said of this telescope?
314. How is the camera obscura made?
315. How do we get a portable camera obscura?
  Il. Explain this by a figure.
316. What is a magic lantern?
  Il. Describe this by a figure.
317. How is the multiplying glass made?
  Il. Explain this by a figure.

ASTRONOMY.

318. What is astronomy?
319. What are the celestial bodies?
320. Of what form is the earth?
  Il. 1. How is it proved that the earth is spherical?
  2. What is meant by antipodes?
  3. What is said of *up* and *down*?
  4. Is the earth a perfect sphere?
321. What is the sensible horizon?
322. What is the rational horizon?
323. How do the sun, moon, and planets appear to move?
  Ob. What occasions this apparent motion?
324. What is the axis of the earth?
325. What are the poles?
326. If we have our backs to the north, how are the other points situated?
327. What is the equator?

328. How are the poles of the heavens situated ?
329. In what does the whole sphere of the heavens appear to revolve?
330. What is the meridian?
331. Why is it called mid-day when the sun comes to the meridian ?
332. What are vertical circles ?
333. What is the prime vertical ?
333. When is a body east or west of the spectator ?
334. What are the cardinal points ?
335. What is meant by the azimuth of a body ?
335. What is meant by the amplitude of a body ?
336. What is said of the sun's rising and setting ?
337. What is the ecliptic ?
337. and *Ob.* What is meant by the obliquity of the ecliptic, and how much is it?
338. Where are the vernal and autumnal equinoxes ?
339. Into what is the ecliptic divided?
340. What are the names of the signs ?
341. In what way do the signs go round the ecliptic ?
342. Which are northern and which southern signs ?
343. What is the zodiac?
Ob. How are the stars in the zodiac divided ?
344. How does the sun appear to move ?
345. What are the tropics ?
346. What are the polar circles ?
347. What is a circle of latitude, and what angle does it make with the ecliptic ?
348. What is the longitude of a heavenly body ?
349. What is the latitude of a heavenly body, and on what is it measured ?
350. What is a circle of declination, and what angle does it make with the equator ?
351. What is the right ascension of a heavenly body ?
352. What is the declination, and on what is it measured ?
Ob. 1. When are heavenly bodies in conjunction ?
When are heavenly bodies in opposition ?
2. What is meant by geocentric longitude and latitude ?
3. What is meant by heliocentric longitude and latitude ?
353. When is a body said to rise and set ?
Ob. 1. What are circumpolar stars?

1. Which is the north star, and how far south is it visible?
2. What stars never rise, and what never set to a person in south latitude?
3. To what is the altitude of the pole equal?

OF THE SOLAR SYSTEM.

354. What are fixed stars?
355. What are planets?
356. What appearances are observed in the moon?
357. What apparent motion has the sun?
358. What appearances have the planets when viewed through a telescope?
358. What is said of the explanation of these phenomena?
359. What is the Copernican system?
360. Of what does the solar system consist?
361. What are the names of the primary planets?
362. Which of the primary planets have moons?
Il. Explain the solar system by the plate.
363. In what direction do the planets move round the sun?
363. In what direction do the moons move round their primaries?
Ob. How have the satellites of Herschel been thought to move?
364. What are the planets' orbits?
365. Of what shape are these orbits?
366. What is meant by a planet's year?
367. What is meant by a planet's day?
368. How do the planets and their moons shine?
Il. What are the appearances of Mercury and Venus through a telescope?
369. Which are inferior planets and why so called?
369. Why are the others called superior?
Il. 1. How is it proved that Mercury and Venus go round the sun?
2. How is it known they are nearer the sun than the earth is?
3. How is it known the other planets are further from the sun than the earth is?
370 When is a planet in conjunction with the sun?
Ob. What is meant by inferior and superior conjunctions?

371. When is a planet in opposition to the s[illegible]?

372. How many conjunctions have the pla[illegible]s in each revolution?

373. What is meant by a transit?

374. Do the planets move fastest when nearer or furthest from the sun?

Ob. Which side of the equator is the sun the longest and how much?

Ob. What is the reason of this?

375. What is the elongation of a planet?

376. When is a planets's motion direct and when retrograde?

Ob. 1. Describe the apparent motions of an inferior planet.

Ob. 1. How does an inferior planet move in inferior conjunction?

Ob. 1. How does it move in superior conjunction?

2. How would the earth appear to move to a spectator at Jupiter?

3. When is the motion of a superior planet direct and when retrograde?

Note. This third observation is printed wrong; it should —read the motion of a superior planet is direct when in conjunction and retrograde when in opposition.

377. What is a tropical revolution?

278. What is a siderial revolution?

Ob. Which is the longest and why?

379. What is a synodic revolution?

Ob. Explain this in Venus and Mercury?

380. What is the sun and how long is it?

381. What is the diameter of the sun?

Ob. Mention the observation to show the great size of the sun.

382. In what time does the sun turn on its axis?

383. What does Dr. Herschel think the sun is?

Ob. 1. What is said of the sun's atmosphere?

Why is the sun brighter at some times than others?

2. Where is the centre of gravity of the solar system?

3. What other motions are the sun and planets supposed to have?

384. What is said of Mercury?

385. What is its diameter and the length of its year?
385. What is [illegible] greatest elongation?
386. What is a transit of Mercury?
Ob. When will the next transits of Mercury visible in this country take place?
387. What is said of Venus?
388. What is her diameter and greatest elongation?
388. and table, page 110. What is the length of Venus' year and day?
Ob. When can Venus be seen in the day time?
289. What is a transit of Venus?
Ob. What is said of a transit of Venus?
Ob. When will the next be visible in this country?
390. When is Venus a morning and when an evening star?
391. Of what use is a transit of Venus?
392. Of what shape is the earth?
393. What is the mean diameter and distance of the earth?
394. What are antipodes?
395. What motions has the earth?
396. and *Il.* Of what is the diurnal motion the cause and why?
Ob. 1. Is the sun nearest to us in summer or winter?
2. Why then is it warmer in summer?
397. What is the length of a year?
Ob. 1. How many days has a common year and how many a leap year?
1. How can we tell a common or leap year?
2. Explain the difference between the old and new styles.
2. To how many days does this difference amount?
3. In what country is the old style used?
398. What is meant by the difference of meridians?
Ob. How many degrees of the equator are equal to one hour?
Ob. Is time later to the east or west of us and why?
399. How long is the light in coming to us from the sun?
399. Is the sun where it appears to be?
Il. Explain this.

400. To what is twilight owing?
Ob. When is the longest and when the shortest twilight?
Ob. What is the zodiacal light, and when is it best seen?
401. Why do the heavens appear bright in the day?
401. What would be their appearance were there no atmosphere?
402. What occasions the blue appearance of the heavens?
Il. What familiar facts tend to prove this?
403 and 404. What does the inclination of the earth's axis occasion?
Il. Explain this by the figure.
405. What is said of the moon?
406. What is her distance from the earth?
407. In what time does the moon turn on her axis?
Cor. What is inferred from this?
407 and 408. What is the length of the moon's year and day?
409. When is it new moon?
410. When is it full moon?
Il. Explain the phases of the moon by the figure.
Ob. What is said of the full moon in winter?
411. Has the moon any moon?
412. Of what size does the earth appear from the moon?
Ob. How are we enabled to see the whole circle of the moon when new?
413. How does the moon shine?
414. Upon what do its changes depend?
415. When is the moon in perigee and when in apogee?
416. What is meant by perihelion and aphelion distance?
417. What is said of Mars and his diameter?
417. What is the length of Mars' year and day?
318. How does Mars appear through a telescope?
Ob. How do the superior planets appear?
419. How is Mars distinguished, and by what is it occasioned?
420. What is said of the apparent size of Mars?
420. When is he brightest and how often does this occur?
Ob. When are other superior planets brightest?
421. What is said of Vesta?
422. What is said of Juno?
423. What is said of Ceres?

424. What is said of Pallas?
 Ob. 1. For what is Pallas remarkable?
 2. What are these planets called and what is said of them?
425. What is the size of Jupiter?
426. What is the length of his year and day?
427. What is the appearance of Jupiter through a telescope?
428. How many satellites has Jupiter and what is said of them?
429. Of what uses are the eclipses of Jupiter's satellites?
430. What is said of the distance of Saturn?
431. What is the diameter of Saturn?
432. What is the length of Saturn's year and day?
433. What is the appearance of Saturn through a telescope?
432. How does the ring move?
 Ob. What is said of the ring?
433 How many moons has Saturn?
 Table, page 110. What are the densities of Mercury, Jupiter and Saturn, compared with water?
 Note.— It will be seen by the table that Mercury is more than nine times as dense or heavy as water, while Jupiter is very little denser than water, and Saturn not half as dense as water.
434. By whom was Herschel discovered and what did he call it?
434. What other name has it?
435. What is Herschel's diameter?
435. What is the length of his year and day?
 Table 110. What is Herschel's density?
 Ob. What is said of Herschel's distance?
436. How is Herschel seen and how many satellites has he?
437. What is said of comets?
438. How do they move and how many are known?
439. When are comets visible?
 Ob. In what direction is the tail?
440. How do the comets shine?
441. What is the number of comets?

442. What is the appearance of a comet?
443. What is said of the tail of a comet?
Ob. Upon what does the apparent length of the tail depend?

OF THE FIXED STARS.

444. Why are fixed stars so called?
445. How are they classed?
446. What is said of their apparent number?
447. How many are visible at once to the naked eye?
448. How are they divided?
449. How do the fixed stars shine?
450. What is said of double stars?
451. What are nebulæ and which is the most remarkable?
452. What is Herschel's opinion of the nebulæ?
453. What are telescopic stars?
454. Have the fixed stars any apparent diameter?
Ob. 1. What did Dr. Herschel say of Lyra?
1. At what distance did he observe clusters of stars?
1. How long would one of these stars continue to shine at the earth if it were extinguished?
1. Which is the nearest star and how long is the light coming from it?
2. How long has the light been in motion that renders stars visible to us?
455. What is said of new stars?
Ob. What are we to understand by the terms fixed stars?
456 and *Ob.* 1. How can we distinguish the stars and planets?
2. How may the twinkling of the stars be accounted for?
3. How may we account for there appearing to be more than there are on a clear evening?
4. In what way do telescopes enable us to see stars, that are invisible to the naked eye?

OF ECLIPSES.

457. When is a heavenly body said to be eclipsed?
458. What eclipses are most striking?
459. Why does the earth cast a shadow behind it?
Ob. Of what shape is this shadow and why?

460. What causes an eclipse of the moon?
Il. Explain the reason of this.
461. When does an eclipse of the moon happen?
462. What would happen if the moon revolved in the level of the ecliptic?
463. How much is the moon's orbit inclined to the level of the earth's orbit?
563. What is meant by the moon's nodes?
464. Why is there not an eclipse at every full moon?
465. When is an eclipse of the moon total and when partial?
466. What renders the moon's surface visible during a total eclipse?
467. To what position of the earth is an eclipse of the moon visible at the same time and why?
Ob. 1, 2, 3. When will the next total eclipses of the moon visible in this country take place?
468. What occasions an eclipse of the sun?
469. When does it happen?
470. To what portion of the earth is an eclipse of the sun visible at the same time and why?
471. When is an eclipse of the sun total, partial or annular?
Why is the moon sometimes capable of observing the whole of the sun and other times not?
472. When would an eclipse of the sun take place to a spectator at the moon?
Ob. When would an eclipse of the moon take place to a spectator at the moon?
Note.—As the moon has always the same side towards the earth, the inhabitants on this side only can have moonlight or see eclipses.
473. What are the greatest and least numbers of eclipses in a year?
474. Of what kind will they be?
Ob. 1, 2, 3, 4, and 5. Mention some large eclipses of the sun that will be visible in this country.
475. What is an occultation?
476. Of what use are occultations?

OF THE TIDES.

477. What occasions the tides?

478. What effect have the attraction of the sun and moon upon the earth?
479. At what place is the highest tide?
480. When is it the highest and why?
481. With what does the oval figure of the waters keep pace?
482. 483. In what time are there two tides and why?
484. Are the two tides of the same height at any place?
485. What are spring tides?
486. What are neap tides?
Ob. When are the highest tides?

ELECTRICITY.

487. What is meant by the electric fluid?
488. What is the natural share of a body?
489. When is a body said to be electrified?
Ex. 1. Mention the experiment with a stick of sealing wax.
2. When is a tube said to be excited?
3. How may a spark be seen, and what accompanies it?
3. What are these phenomena called?
4. Describe the experiment with a piece of metal.
5. Describe the experiment with a piece of glass.
490. What is meant by conductors of electricity?
491. What is meant by non-conductors?
492. Mention some conducting substances.
493. Mention some non-conducting substances.
494. When do all substances become conductors?
495. When is a body positively electrified?
495. When is a body negatively electrified?
496. When is a conductor insulated?
Ex. Illustrate this by an experiment.
497. What is the principal method of exciting electricity?
498. When is a conductor most powerfully excited?
Ex. 1. and 2. Mention the experiments with a glass tube.
499. When do electrified bodies repel each other?
500. When will they attract each other?
501. How may the person that rubs the tube become electrified?

501. Will the electricity acquired by the person be the same as that acquired by the tube?

Ex. 1, 2, 3. Mention the experiments to show the difference between the electricities acquired by the tube and man.

4. What will be the consequence of the person's rubbing a piece of sulphur or sealing wax?

Cor. What are the two electric states sometimes called, and why?

502. Do these electricities accompany each other, and why?

503. What difference is there in communicating the electric fluid to a conductor and non-conductor?

504. If one side of a piece of glass is positive, in what state is the other side?

505. How may the two electricities be brought together?

506. What is meant by the electric shock?

507. What are the electrical machines?

Il. Describe one by the figures.

OF ELECTRICAL ATTRACTION AND REPULSION.

508. When do electrified bodies repel each other?

508. When do they attract each other?

Ex. 1. Mention the experiment with a tuft of feathers.

2. Mention the experiment with a large feather.

3. Describe the experiment of the *flying feather.*

4. Describe the experiment with two metallic plates.

5. Describe the experiment with two pith balls.

6. For what may these balls be used?

509. What is an electrometer?

Ex. Describe a quadrant electrometer by the figure.

510. When may the electric spark be seen?

511. When will the electric fluid pass from a positive to a negative body?

512. What is meant by the electric shock?

513. Is the motion of electricity rapid?

514. When will a body become electrified without being rubbed or touching an electrified body?

Ex. Illustrate this by an experiment.

515. Will electricity spread on glass, and why?
516. How may electricity be communicated to the whole surface of glass, and what is this called?
517. How is a coated and charged glass discharged?
518. What shaped glasses are used in electrical experiments?
519. What is a Leyden phial, and why so called?
Il. Explain its structure by the figure.
Ex. 1. Explain the manner of using it.
2. Explain the discharging rod.
3. How may a person take a shock?
4. How may several persons take a shock?
4. Is the motion of electricity rapid?
520. What is an electric battery?
Il. Explain it by the figure.
521. What is said of the effects of electricity by the battery?
Ex. 1. Describe the experiment with a wire.
2. Describe the experiment with gold leaf between glass.
3. Describe the experiment with gold leaf between cards.
4. How may gunpowder be fired?
522. How are buildings defended from lightning?
523. How does electricity appear when it enters a point?
523. How does it appear when it leaves a point?
524. What instruments may be put in motion by electricity?
525. What is lightning?
526. What is thunder?
527. What chimney is most likely to be struck, and why?
528. How is electricity carried into the atmosphere?
528. When does it accumulate?
Ob. 1. How is it proved that electricity is carried into the atmosphere by evaporation?
2. Why have we more lightning in summer than in winter?
529 What is the aurora borealis?
530. Upon what does earthquakes, &c. depend?

GALVANISM.

531. What is galvanism, and whence its name?

532. What is the difference between electricity and galvanism?
533. What parts of animals are most easily affected by the galvanic fluid?
534. When, and how did Galvani discover it?
535. How can motion be produced in dead animals?
Ex. 1. Describe the experiment with a fish.
2. Describe the experiment with a piece of metal above, and one below the tongue.
3. Describe he experiment with a piece of tinfoil on the bulb of the eye.
536. How are galvanic conductors divided?
537. What are the perfect conductors?
538. What are the imperfect conductors?
539. What is the simplest galvanic combination?
539. When is the combination of the first order, and when of the second?
540. What is necessary in galvanic combinations?
Ex. Describe a battery of the first order.
541. What parts are in opposite electric states?
542. How may the galvanic effects be increased?
543. What are these repeated combinations called?
Ex. 1. Describe a galvanic pile.
2. Describe the battery with a row of glasses.
3. Describe the most convenient battery.
4. How may a galvanic shock be taken?
544. What effects are produced by a galvanic battery?
Ex. 1. With what may the trough be filled, and how is it used?
2. What substance may be burned?
545. What is said of explaining familiar facts by galvanism?
Ex. 1. What is said of drinking porter?
2. What is said of eating eggs?
3. What is said of mercury?
4. What parts of metallic works tarnish first?
5, What is said of the sheathing of ships?
546. What fish have the power of giving shocks?

MAGNETISM.

547. What is magnetism?

547. What is the natural magnet?
548. What are artificial magnets?
549. Upon what do magnets act?
550. What do magnets attract?
551. In what position does a magnet at liberty place itself?
552. What is meant by the poles of a magnet?
553. What is meant by the directive property?
554. What is the magnetic meridian?
555. What is meant by the declination of the magnet?
556. Which poles repel, and which attract each other?
557. What is meant by the dipping of the needle?
558. To what may a magnet be made to impart its properties?
559. When is a piece of iron attracted by a magnet?
559. At what part of the magnet is the attraction strongest?
560. Does a magnet attract iron as well when a body is placed between them?
561. Which is attracted most powerfully, iron or steel?
561. Which retains the magnetic property longest?
562. How is the magnetic power weakened or destroyed?
563. How is the magnetic power increased?
564. Which pole is most powerful in north, and which in south latitudes?
565. On what account is a magnet useful to seamen?
566. In what way is it useful to seamen?
567. What is a mariner's compass?
568. What is meant by the declination of the needle?
569. When is this declination called east, and when west?
570. How much is it now?
571. What is meant by the dip of the needle?
572. What is a dipping needle?
573. When will a piece of iron become a magnet?
574. When will a bar of iron become magnetical?
575. How may iron be rendered magnetical by heating?
576. What effect has electricity on iron?
577. How are artificial magnets made?
578. Is the power of a magnet diminished by imparting its properties to other bodies?
579. What effect will two or more magnets have?

580. How is a magnetic needle made?
Il. Explain the magnetic needle by the figure.
Il. Explain the structure of the mariner's compass.

ON HEAT OR CALORIC.

581. What is heat or caloric?
Ob. How are these terms applied?
582. What is caloric supposed to be and why?
583. To what may all the effects of heating and cooling be reduced?
Ob. How do we see our dependence upon heat?
584. What is said of heat and cold?
Ex. How may a body be made to feel hot and cold at the same time?
585. What is cold and how do bodies move?
586. What effect does heating and cooling have on bodies?
Ob. 1. What effect has heat on ice and water?
1. What is the consequence of taking heat from vapour, also from water?
2. In what way do mechanics use the expansive property of heat?
587. What is the consequence of compressing bodies?
588. What is the consequence of bodies expanding?
Ob. When do bodies give out and when absorb heat?
Ex. 1. Why do a person's hands feel colder when wet?
2. Why does a piece of metal become hot when hammered?
3. When is heat produced by mixing two fluids?
589. To what has heat a natural tendency?
590. Does heat pass with the same ease through all bodies?
Ob. 1. Mention some good and some bad conductors.
2. What substances are best clothing in winter?
3. What substances keep ice best in summer?
591. Does a good or bad conductor feel the coldest and why?
591. To what is the sensation of heat and cold in proportion?
592. Does a good or bad conductor feel the hottest and why?

Ex. Describe the experiment with a purse and money.
593. Have all bodies the same capacity for heat?
Ex. Has a dense or rare body the greatest capacity for caloric?
594. How is a body susceptible of different states?
Il. Illustrate this by ice and water.
595. What is combined caloric?
Il. 1. Illustrate this by ice.
Il. 1. What other name has combined heat and why?
2. What are fluids and vapours?
3. Which contains most latent heat, solids, fluids, or vapours?
3. What effect is produced on surrounding bodies by freezing, and why?
596. What is meant by free caloric?
596. What is the temperature of a body?
Il. Illustrate the definition of free caloric.
597. What are thermometers?
597. What fluids are mostly used in constructing thermometers?
598. What thermometer is used in this country?
Il. 1. What are the freezing and boiling points of water?
1. What are the freezing and boiling points of Mercury?
2. Describe Reaumur's thermometer.
599. Do fluids expand equably?
600 When is a body expanded most by a certain portion of caloric?
Ob. 1. Explain the reason of this.
2. What is said of water and other bodies expanding?
3. Why does water expand upon freezing?
4. What effect has this upon a glass vessel containing water?
601. How hot can water be made, and why can it not be made hotter?
Ob. What causes the danger of dropping water into melted metals, &c.?
602. How can water be heated so as to melt lead, &c.?
602. What is the vessel for this purpose called?
603. What promotes the evaporation of water?
Il. 1. Illustrate this.
2. How is it shown that evaporation does not depend upon air?

604. At what temperature will sea water freeze?
604. Is it ever all frozen?
Ob. 1. How may sea water be purified?
2. How may spirits be concentrated?
605. What are the sources of heat?
606. From which of the celestial bodies do we derive heat?
Ob. What is said of heat from the moon?
607. Which is the most generally used source of heat?
607. What is fire?
Ob. 1. How are solid bodies heated?
2. Upon what principle is the heat from compression produced?
608. Are incompressible substances heated by pressure?
Il. 1. Illustrate this by flint, water and air.
2. What is meant by annealing?
609. What is the third developement of heat?
Il. 1. Illustrate this.
2. Does every mixture change temperature?
2. What is remarkable in those that do?
610. Whence arises the heat during combustion?
Ob. 1. From whence does the light arise?
2. Whence is the light in burning candles, &c.?
611. How is heat propagated?
Il. How is the air in a room heated?
Il. 1. Is the air in the upper or lower part of a room the warmer?
Ex. Describe the experiment with a candle in a door.
Il. 2. How is water boiled?
612. How does water freeze?
Ob. 1. Why are places surrounded with water, warmer than others in the same latitudes?
2. Why do not deep lakes freeze?
613. Will water be heated soonest by applying heat at top or bottom?
614. When does water give out heat?
615 and *Il.* What retards a fluid's heating?
616. What is meant by radient caloric?
Ob. 1. Are the rays of heat and light the same?
2. Upon what does the quantity of caloric radiated depend?

617 and *Ob.* What becomes of the rays of heat that fall on a body?

618. What surfaces reflect heat best?

618 and *Ob.* How may the rays of heat be converged to a focus?

Ob. Is a finely polished metal heated by the rays of caloric that falls on it, and why?

619. What coloured bodies absorb most heat?

Ex. Prove this by an experiment.

Ob. Are transparent bodies heated by the rays of caloric passing through them?

Ob. How is the air heated?

620. What bodies radiate most heat?

Cor. What kind of a vessel should be used for heating a fluid?

Cor. What kind to keep it hot?

621. On what principle are burning glasses constructed?

Ob. 1. In what part of the solar spectrum is the greatest heat?

622. What is animal heat?

Ob. 1. By what is it produced?

2. What tends to prove this?

623. Why does a person feel cooler in a current of air?

Ob. 1. Why is the same heat more oppressive in damp weather?

2. To what extremes of temperature have men been exposed without injury?

624. When is moisture precipitated and why?

Il. 1. Illustrate this by a pitcher of ice water.

2. What renders a person's breath visible in cold weather?

2. What renders steam and vapour visible?

625. What is the cause of rain?

626. What is the cause of dew?

627. What is snow, and why is the air warmed by snowing?

628. What occasions hail?

Ob. How may hail in warm weather be accounted for?

GLOSSARY

OF TERMS USED IN THIS VOLUME.

ACCELERATED, one increase of swiftness continually added to a former increase.

Acoustics, the science that treats of sound in general.

Action, the power of one body exerted on another.

Acute, shap; ending in a point; the highest sound of an instrument.

Adhesion, the union of two bodies simply touching each other.

Adulterated, the mixture of some base matter.

Affinity, a term used to express that property which different species of matter have to unite with each other.

Air-pump, a machine by which the air contained in bodies may be exhausted, see p. 56.

Amalgam, a mixture of mercury with some other metal, as tin, &c.

Analogous, bearing some resemblance or proportion.

Andlysis, the resolution of a substance into its constituent parts.

Angle, the ends of two lines inclining to, and meeting each other, forming an opening or corner, called an angle.

Animalculæ, the smallest of all possible insects, which without the help of glasses, escape the most piercing eye.

Apex, top, point, or summit.

Aphelion, the greatest distance of a planet from the sun.

Apogee, the greatest distance of a planet from the earth.

Apparatus, things to be provided for the purpose of experiments.

Aqueducts, conveyances for water.

Astronomy, the science which relates to the celestial bodies.

Atmosphere, the air that surrounds the globe of the earth.

Atoms, the most minute and invisible parts of which bodies are formed.

Axis, a direct line passing through the centre of any body on which it may turn.

Balance, lever of the first kind, p. 30.

——— hydrostatical, p. 49.

Barometer, an instrument which shows the variation of the pressure of the atmosphere. See p. 59.

Battery, electrical, p. 146.

Bellows, hydrostatical, p. 47.

Bodies, all those things which can be called substances, have a shape or form, and may be felt or known by the senses.

Capacity, the quantity of room that a body has to receive other bodies within it.

Capillary tubes, small tubes resembling hairs in their capacities.

Cardinal point, one of the four principal points in the compass; the north, south, east and west, are the four cardinal points.

Catoptrics, that part of optics which treats of vision by reflection.

Cause, that which produces an effect.

Centre of Gravity, a point of a body, on which, when suspended, it will rest.

Choroides, one of the coats of the eye.

Cohesion, the force inherent in all substances which prevents them from falling to pieces.

Combination, the different ways that quantities of substances may be varied in order to produce a new form.

Compass, an instrument dividing the horizon into 32 equal parts; by this instrument mariners steer their course See p. 156.

Composition, a mixture of different ingredients to constitute one whole.

Compound, a substance made up of many ingredients.

Concussion, the act of bringing the parts of a body nearer to each other.

Concave, a regular curved hollow.

Condensation, the same with compression.

Contraction, that kind of motion which makes a body shorten itself.

Converging rays, rays which incline towards each other till they meet in a point.

Convex, a round form like the top of a watch glass; as a concave is hollow, like the inside of a watch glass.

Cornea, the second or horny coat of the eye, containing the watery humour.

Corpuscula, the smallest of all bodies.

Cubic inch, is an inch square, made into a solid body like a die, whose length, breadth and depth are equal.

Cylinder, a body having two flat surfaces and one circular; a tube or pipe completely round and uniform from one end to the other is a cylinder.

Density, thickness; or that property by which bodies contain a certain quantity of matter under a certain bulk; so that more matter under the same bulk is greater density.

Diagonal, a line drawn from angle to angle, and dividing a square into equal parts.

Diameter, a straight line passing through the centre of a circle.

Diaphanous, transparent, allowing the light to pass through, as glass, air, water, &c.

Dilatation, the act of becoming thin and wide, so as to preserve the same quantity of matter, but to acquire a larger volume; contrary to contraction.

Dimension, the measure of a body, either as it is long, broad or deep.

Dioptrics, that part of optics which treats of the different refractions of light passing through different mediums, as air, water, glass, &c.

Disk, the face of the sun or moon being round, and appearing to our sight as flat.

Divergent rays, rays which, going from the point of any visible object, depart from each other.

Divisibility, see p. 10.

Ductility of metals, the quality that metals have of becoming flexible, pliable, and of being extended.

Effervescence, an intestine motion which takes certain bodies, occasioned by the escape of t ous substance.

Effluvia, the small and insensible particles that fly bodies.

Elasticity, the power which a body has to return t situation, as a cane that is forcibly bent fl again.

Electrical, bodies which have the power of attract substances to them without magnetism; aml ing-wax, &c. when excited by friction, are of cription.

Elements, the original, unmixed simple parts c which are incapable of decomposition.

Emanation of light, flowing round in all directio a source or centre, as the rays of light from a from the sun.

Equilibrium, equipoise, equality of weight at each

Evaporation, the conversion of fluids into vapour

Exhale, throwing forth vapours from the surface on

Expansion, the swelling or increase of bulk.

Experiment, a trial made on natural bodies for the of discovering the qualities or their properties certaining their causes and effects.

Facis, small surfaces; a superficies cut into severa

Fibres, fine ligaments or strings, tough and long, dle part of which is very fleshy.

Filaments, thin, slender threads; also small fibr make up the texture of the muscles.

Fluids, any thing not solid; bodies which are su be made up of particles so very small and ro they are easily put in motion.

Finite, that which has an end; it also means deterı

Focus, the point wherein the rays are collected a have undergone refraction or reflection.

Foci, plural of focus.

Form, the external appearance or shape of any t

Frangible, easily broken.

Friction, the rubbing of two or more bodies aga other.

Fulcrum, a prop.

Fusion, the act of melting, the state of being melted.

Galvanism, see p. 149.

Gas, all solid substances when converted into permanently elastic-fluids by means of heat, are called gases.

Globules, small round bodies.

Grain, the weights here following are generally used in the experiments of natural philosophy.

One pound contains 12 ounces, or 240 penny weights, or 5,760 grains.

One ounce contains 20 pennyweights, or 480 grains.

One pennyweight contains 24 grains.

Gravity, weight, heaviness, tendency to the centre.

———, specific, see p. 47.

Hemisphere, the half of a globe, or sphere.

Heterogeneous, consisting of parts unlike each other.

Horizon, the line that terminates our view of the sky.

Horizontal, level with the horizon.

Humours, parts of the eye, of which there are three, the *aqueous*, the *crystalline*, and the *vitreous*, see p. 89.

Hydraulics, the science that teaches how to estimate the force of fluids in motion.

Hydrometer, an instrument for obtaining the specific gravities of liquids.

Hydrostatics, the science which treats of the nature, gravity, pressure and motion of fluids, and of weighing solids in them. See p. 44.

Hypothesis, supposition; principle laid down, and to be taken for granted.

Igneous, the property of those bodies which communicate fire.

Impelled, pushed or driven onwards.

Inch square, is a portion of any substance of four equal sides, every one of which is an inch in length.

Inclined plane, a surface that slopes or inclines to the level of the horizon; one of the mechanical powers. See p. 35.

Inertness, the state of being quite still.

Infinite, without end; indeterminate.

Inflexibility, incapable of being bent.

Integrant parts, are those which collectively make up a whole body.

Interstice, space between one thing and another.

Layer, a thin covering of any one substance spread upon another.

Lens, a glass made of a peculiar shape. See p. 74.

Lever, any contrivance to enable us to raise a body that is either too heavy or too inconveniently placed to be raised by the mere strength of the arm: one of the mechanical powers. See p. 29.

Line of Direction, is that line which proceeds from the centre of gravity to the earth.

Magic lantern. See p. 98.

Matter, is every substance that may be felt, divided, put in motion, or stopped, and is extended in length, breadth and depth.

Mechanical powers. See p. 28.

Medium, any substance through which bodies move, as air, water, vapour, &c.

Media, plural of medium.

Microscope, an instrument by means of which the most minute objects are made apparent to the eye, and every part distinct. See p. 94.

Mirror, any polished body that forms images of objects by reflection. See p. 80.

Moving powers. See p. 40.

Muscles, the principal organs or promoters of motion in all animated bodies.

Non-elastic, bodies that do not restore themselves to their former figures after having been struck or bent by other bodies.

Oblique, aslant, or forming an angle with the perpendicular line.

Obtuse, blunt, the contrary to acute.

Oleaginous, partaking of the nature of oil.

Opacity, cloudiness, want of transparency,

Opaque, dark, obscure, cloudy, the contrary to transparent.

Optics, the science which explains the properties of light. See p. 68.

Organ, the instrument of some faculty; thus the eye is the organ of sight.

Parallel, lines are parallel to one another, when they are every where equally distant from each other.

Particles, the very smallest points or atoms that can be conceived to enter into the composition of bodies.

Pendulum. See p. 42.

Physics, natural philosophy, or that science which treats of the powers and properties of bodies in their natural state.

Plane, a flat surface, level with the horizon.

Pneumatics, the doctrine of the air, and of the effects dependent on its properties. See p. 53.

Plane, inclined, one of the mechanical powers. See p. 35.

Pores, small openings found between the particles of all bodies.

Prism, a prism of glass is a glass bounded with two equal and parallel triangular ends, and three plane sides. See p. 85.

Process, the way of proceeding in, and conducting any experiment.

Proportion, comparative relatian of one thing to another: ratio.

Pulley, one of the mechanical powers. See p. 34.

Pump. See p. 50,

———, *forcing*. See p. 51.

Pyrometer, an instrument for ascertaining the expansion of solid bodies by heat

Quality, that property by which one thing is distinguished from another.

Quantity, that property of any thing which may be increased or diminished.

Quotient, in arithmetic, the number produced by the division of two given numbers one by the other.

Rarefaction, the same with dilatation.

Ray, a beam of light emitted from a luminous body.

Radius, a line which proceeds from the centre of a circle and ends in its circumference.

Recipient, or receiver, that part of the air-pump which incloses the bodies that are put therein.

Reflection, of the rays of light, is their return, after their approaching so near the surfaces of bodies as to be driven backwards.

Refraction, of the rays of light, is when they pass obliquely out of one medium into another.

Relation, the connection that two quantities have to each other with regard to their size or magnitude.

Repulsion, a principle whereby the particles of bodies are prevented from coming into actual contact.

Retarded, velocity or swiftness continually diminished.

Retina, the expansion of the optic nerve on the inner surface of the eye, is so called from its resemblance to a net.

Reverberation, the act of a body repelling another after its striking on it.

Rotation, a wheeling round itselt.

Science, a clear, obvious, and certain knowledge of things founded on truth.

Scintellation, sparkling; the trembling and twinkling motion of the stars.

Sclerotica, one of the coats of the eye.

Screw, one of the mechanical powers, see p. 38.

Simple bodies, the same with elements.

Sine, a right line drawn from one end of an arch perpendicularly upon the diameter drawn from the other end of that arch.

Siphon, an incurvated chymical tube or pipe.

Solar, belonging to or proceeding from the sun.

Solids, the parts containing the fluids: hard bodies, having length, breadth, and thickness.

Solution, the perfect union of a solid substance with a fluid.

Space, room, local extension, any quantity of place or of time.

Spectrum, See p. 85.

Sphere, a globe: a body of which the centre is at the same distance from every point of the circumference.

Substance, being; something existing; solid, not empty; that which makes a being perceivable by the senses.

Superficies, the whole of the outward parts of bodies; surfaces.

Surface, superficies, outside; that of which we only consider the length and breadth.

Syringe, a pipe through which any liquor is squirted.

Tangent, a line that just grazes the surface of a circle, or touches it in only one point.

Telescope, an instrument for viewing distant objects. See p. 96.

Tension, a bending or stretching out by the force of another body: the state of being stretched.

Tenuity, thinness; smallness, minuteness.

Texture, the manner in which the elements of any particular body are interwoven with each other.

Thermometer, an instrument to show the relative heat of bodies.

Vacuum, a space unoccupied by matter.

Vapours, the minutest particles of any fluid raised into the air by means of heat.

Velocity, swiftness; the property of a moving body to run over a certain quantity of space in a certain portion of time.

Vertical, in a direction perpendicular to the horizon.

Vibration, the quivering of a musical string with quick or slow motion producing sound.

Vitrify, to change into glass.

Void, a vacuity or space wherein nothing is contained.

Volatile, bodies that are apt to evaporate are said to be volatile.

Volume, the quantity of room that any substance or body takes up in space.

Vortex, a fluid of any kind, in which the suction is circular.

Undulation, a motion like that of the waves, waving to and fro in the air.

Unison, one and the same sound; the agreement of two notes or strings of an instrument in one and the same tone.

Water, a transparent elementary liquid, tasteless, without colour or odour.

Wedge, one of the mechanical powers; a body with a sharp edge. See p. 37.

Week, contains 7 days. 168 hours, or 10,080 minutes.

Wheel and axis, one of the mechanical powers. See p. 33.

Zenith, the point in the heavens over head.

Zodiac. See p. 104.

Zone, a division of the earth, with respect to the different degrees of heat found in different parts; there are the *torrid*, the two *temperate*, and two *frigid* zones.

FINIS.

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MAR 18 1955